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S. HERBERT COX,

ASSOC. R.S.M., M.INST. M. AND M., F.G.S., ETC.; MINING AND CONSULTING ENGINEER.

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PREFACE.

The object of this volume is to give a sketch of those subjects which underlie the calling of the Prospector, without encroaching to any great extent upon the provinces occupied by the sciences of Mineralogy and Geology, or the arts of Mining and Metallurgy, which are too far reaching to allow of more than the briefest mention in a work of this sort.

It is evident, therefore, that the scope of the work must be necessarily limited, but it is hoped that to the practical Prospector it may give certain hints as regards the recognition of Minerals with which he is unacquainted, while, to the student, it may afford an introduction to the subject which will be of use in directing his work into the proper channels.

S. H. C.

London,
January, 1898.

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PROSPECTING FOR MINERALS.

CHAPTER I.

INTRODUCTION AND HINTS ON GEOLOGY.

METALS and Minerals occur in Nature with such varying forms, and distributed under such different conditions, that it is impossible to enunciate laws regarding their mode of occurrence, without giving so many exceptions that the value of the laws might be called in question. On the other hand, the minerals themselves are easily recognised when found, if ordinary intelligence is brought to bear in testing them.

Certain metals and minerals, such as gold and the various ores of copper, which can be recognised readily without any special tests being applied, attract a large amount of attention from prospectors who have not had any scientific training; whilst those minerals which require some skill to determine are, as a general rule, passed over by the same men.

Apart from the ease with which gold is recognised, its intrinsic value, the absence of fluctuations in the market price, and the certainty that no difficulty will ever be experienced in disposing of it, no matter in what quantity it is found, give an attraction to mining for gold which is not shared by any other metal. But, although gold possesses all these advantages, it is quite as difficult to determine whether some gold-bearing deposits can be worked to a profit as it is to decide a similar question regarding tin, lead, antimony, or zinc.

There are a number of scientific questions which bear directly or indirectly upon the occurrence of minerals, and it is found that certain minerals are generally associated with certain rocks; but, while this is the case, there would be no work for the prospector if the presence or absence of ores could be deter-

mined by an examination of the geological structure of a district.

There is a glamour about a prospector's calling which induces many to undertake the work in which comparatively few succeed. The independent life, the change of scene, the chance of making discoveries day by day and of becoming wealthy in a moment, lead many to prefer this to the work of more settled mining districts where good wages can be earned. The true prospector never leaves his adopted calling permanently; if pursued by bad fortune until his resources have come to an end, he will migrate to a mining camp and work for wages for a time; but, as soon as occasion offers, he returns to the field and continues to search for the Eldorado that he always feel confident he will discover.

There is little that a book can teach such men regarding the search for gold, but it is possible that they may obtain hints which would induce them to abandon worthless undertakings, and also learn to distinguish, roughly, minerals which are not of common occurrence, but are still of value.

For the student who is preparing to embark on his career, some detailed information is necessary, and some little time must be devoted to a general description of mineral deposits, their probable origin and modes of occurrence, before investigating the conditions which are peculiar to individual groups of ores.

It does not appear advisable to enter into the theoretical questions of geology, and in these pages it will be assumed that a general knowledge of the principles of that science has already been acquired; there are, however, a few points which require to be emphasised.

Geological Age.—From the prospector's point of view the geological age of the rocks is a matter of very little importance, and this cannot be too clearly understood. It is true that in certain countries there are deposits of mineral which are associated with rocks of special geological age; as, for instance, the coals of the European coalfields with beds of the Carboniferous system; but when other countries are visited it is found that, although seams of coal exist, they frequently belong to other geological periods; and the rocks of the Carboniferous system are of an entirely different nature. Not to multiply instances, it may be mentioned that in New Zealand the Carboniferous rocks consist of indurated sandstones and slates, in which no traces of coal are found, whilst the coals themselves are of Cretaceous age and, in some cases, even younger.

As a further illustration, gold-bearing reefs are found traversing schistose rocks, diorites, &c., in Western Australia; in Lower Silurian strata in Victoria; in Upper Silurian and Lower Devonian strata in New South Wales; in Carboniferous and Upper Devonian strata in New Zealand, and in the same colony the auriferous reefs of the Thames Goldfield intersect submarine volcanic rocks which are certainly not older than Cretaceous and may be little older than Miocene. It will thus be apparent that whatever other guides may be of importance to the prospector, but little can be gained from a scientific knowledge of the geological age of the rocks. We have to go to each new district with an open mind, and be prepared to find the conditions prevailing different in many features from those to which we have been accustomed elsewhere. The nature of the deposits must be studied, points of resemblance to other localities noted, and differences investigated so that a true appreciation of the value of the mineral deposits can be formed.

General Observations.—It is not intended to convey the idea that experience gained in one locality will not be of any value in another; for there are many features which are the same wherever one may go, and, after investigating the mode of occurrence of mineral deposits, a few of the more important of them will be enumerated for the guidance of students. It is important to cultivate a general eye for country, and be able to determine from a casual inspection whether any particular district presents features which render it possible that mineral deposits will be found; and, at this point, a broad distinction must be drawn between those which are found *in situ*, or associated with the rocks themselves, although under varying conditions, and which will be called in these pages "Mineral Deposits"; and "Alluvial Deposits," which have been worn from their parent rocks, and re-arranged in the gravels or sands of rivers, on sea beaches, or in certain glacier drifts.

Mineral Deposits occur under a great variety of conditions, which will be dealt with later; but, so far as their association with the containing rocks is concerned, the same remarks will apply to each.

It is seldom that the principal mountain range of a country is the more important repository of minerals, but those ranges which flank the main range often contain these deposits. It is quite possible that the reason of this is that the rocks composing the principal ranges are harder, and less liable to disintegration and decomposition than those of which the flanking ranges are composed; for the harder rocks, unless interstratified with those

of softer texture, are not so congenial to mineral deposits as those which are subject to decomposition when exposed to the atmosphere. It appears, therefore, that, as the harder rocks seldom contain mineral deposits of importance, the higher ranges must, as a rule, be less productive than those of lesser elevation. It must not be supposed, however, that the really soft rocks are those in which mineral deposits are most likely to be found; for, unless a rock is indurated to some extent, it is hardly likely to contain mineral deposits of value; it thus appears that rocks of medium hardness are generally the most promising, and that those which decompose readily, and form a considerable quantity of oxide of iron in the process, are, generally speaking, the more worthy of attention.

The physical condition of the rocks also requires to be studied. Whilst the actual angle of bedding, whether flat or steep, appears to exert very little influence on the value of the deposits, it is seldom the case, where rocks have been subjected to much contortion, where, in fact, they are bent and twisted into many sharp anticlinal and synclinal folds, that they contain mineral deposits of a permanent nature.

The intersection of sedimentary strata by igneous dykes may, generally, be looked upon as a favourable indication, more especially when these are of a hornblendic or augitic nature, such as diorite or diabase; but this condition, like the last, must not be taken to apply where the strata are greatly disturbed by the intrusions. There are certain rocks, such as limestones and serpentines, in which very irregular deposits of mineral occur, and which do not follow any known rules, and in rocks of this class valuable, though very erratic, deposits are occasionally found.

It will thus be observed that what one has chiefly to depend upon, in deciding whether a new district is worthy of the attention of the prospector, is a development of an "eye for country," which can only be acquired by practice, bearing in mind the hints given above.

Alluvial Deposits are those which are derived from the parent rocks by denudation, and thus the general remarks regarding the nature of the country will generally apply to these deposits as well; but there are certain points relating to them which deserve special attention at this early stage of the subject.

Those alluvial deposits which occur near their parent rocks are governed absolutely by the conditions already quoted, but, seeing that the denudation which produced the sands and

gravels in which alluvial gold and other precious metals are found has operated during long periods; that, in some instances, this denudation has been on a gigantic scale, while the amount of gold included in the gravels formed is only small; that subsequent cross-drainage may have concentrated this gold in the beds of streams until it is in sufficient quantities to be of value, and that the gold may have been transported for great distances from the point from which it was originally broken; it behoves the prospector to test any beds of gravel or other alluvial deposits he may find, by panning, in order to satisfy himself whether or no any metal or mineral of value occurs in them.

It is not only on the surface, in the beds of streams, that alluvial deposits may exist, but they are frequently found buried at some depth below the surface soil; in these cases shafts have to be sunk until the bed rock is reached, on which the metal is generally richer than in the overlying drift. There are also numerous instances in which the contour of the country has been completely changed since the deposits were formed, and many cases might be cited in Australia in which old river beds, carrying both gold and tinstone, have been buried below sheets of basalt, necessitating heavy expenditure in testing the deposit before it can be decided whether the metal occurs in sufficient quantity to make it payable to work.

It must be obvious that very few surface indications of deposits of this sort can be looked for, and, although a prospector well acquainted with a district may be able to form conclusions, it is quite impossible for a new arrival to do so with any degree of certainty, without having recourse to a study of the work of previous observers on the structure of the country; and here it is of importance to mention the fact that in every civilised part of the world a great deal of information, of a reliable nature, is available regarding the geological structure of the country, and the experience that has been gained as to the distribution of minerals. The respective governments employ geologists, surveyors, and other officials to investigate these points, and to report concerning them; and it is of the greatest assistance to any new arrival to procure these reports and study them carefully.

Conditions which have to be Studied.—It must be borne in mind that the prospector has not only to find mineral which is in itself intrinsically valuable, but must also know enough regarding the methods of working, the costs of different processes, &c., to determine whether the metal or

mineral is present in sufficient quantity to make the deposit of value.

There are many considerations that will affect a decision on this point; for, in certain cases, deposits of very low value can be worked, whilst in others, even moderately rich ores are worthless because the conditions that prevail are not favourable. While it is beyond the limits of a book of this sort to enter at all fully upon so important a subject, it will be well to indicate in some way the points which require special attention. Naturally, the first question is the richness of the ore; a question which can, in certain cases, be answered approximately by an examination of it, by panning tests, or by assay of carefully-taken samples. In testing this question, it must always be borne in mind that the value of mineral deposits will vary within a distance of a few feet; hence constant sampling should be undertaken at every point available, so as to decide the extent and value of the richer and poorer portions of the deposit.

It is obvious that a deposit only becomes of value when sufficient ore has been shown to exist to make it certain that it will pay for extraction, and when it is known what treatment may be necessary. Until that time the deposit is only a **prospect**, and, as such, comes within the province of the prospector.

Having tested a deposit in this manner and arrived at a knowledge of its intrinsic worth, other points require attention.

Is water power available to enable the mine to be worked at a minimum cost, and what expense is likely to be incurred in utilising this?

Do facilities exist for transmitting, by means of electricity, power generated by water at a point some distance from the deposit?

Is there sufficient water available for the mechanical or metallurgical operations that will have to be carried on?

Is there much or little water in the mine which will have to be pumped?

Is fuel available in large quantity and at a reasonable cost?

Is labour good, plentiful, and cheap?

Can mining timber be procured cheaply and of good quality?

Is there a good and suitable site on which machinery can be erected?

What facilities of communication by rail or road exist, and what is the cost of freight?

Is the ore of a refractory nature, or can it be easily treated for the recovery of the metal it contains?

Do special facilities exist which make mining very cheap?

It is upon the answers to these questions that the value of a deposit will depend, seeing that, in some cases, mines are worked and mineral extracted with large profits from ores which are not intrinsically worth more than 10s. or 12s. per ton; while, in other cases, ores that have a value of £4 or £5 per ton, or even more, will not pay to work, because the conditions are not favourable.

It must be clearly understood that only very large deposits can be worked which are of so low a grade as those first mentioned, because it is only by treating large quantities that the cost of extraction can be brought to a minimum, and an operation of this sort will involve a very large expenditure of capital at the outset. It is difficult to further define the conditions which must be fulfilled, so that the prospector must rely upon his own judgment to a very great extent, bearing in mind the points already alluded to.

Rocks.—In the mineralogical portion of this book allusion will be made to the rock-forming minerals, and it is now proposed to give some account of the combinations of minerals which compose the different rocks, as well as the physical conditions under which they occur.

Rocks may be divided into two great groups, viz. :—Those which are of **eruptive** origin, or were, at the time of their formation, in a plastic state induced either by fusion or the influence of heat in the presence of moisture; and those which are of **sedimentary** origin and have been deposited by the agency of water under conditions very similar to those which now prevail upon the earth's surface.

The latter group, however, is capable of further subdivision into **mechanically** and **organically** formed rocks; while the former may be subdivided according as they were formed at great depths below the surface of the ground, like the granites; were intruded as dykes, like the Cornish elvans; or poured forth from volcanoes, like the basalts.

These subdivisions, both in the eruptive and stratified rocks, are not clear and well defined, but merge one into the other. Granites and basalts, for instance, both occur as dykes; whilst calcareous sandstones are formed partly mechanically and partly by organic means. It is not proposed to give any long description of the operations of Nature in producing these rocks,

but simply to give ready means for distinguishing the different classes of deposit.

Igneous or Eruptive Rocks.

Igneous rocks are either of hydrothermal, trappean, or volcanic origin, and any classification should at the outset take this division into consideration.

The hydrothermal rocks include all those of granitic character, such as granite and syenite, and their various modifications, which are characterised by the presence or absence of special minerals. It will be sufficient here to mention that **Granite** is a crystalline granular admixture of the minerals, orthoclase, mica, and quartz; and that **Syenite** consists of orthoclase and hornblende. There are a number of intermediate rocks, some of which will be found in the table on p. 9; but the limits of this book will not permit of details.

These rocks have apparently been formed at great depths below the surface of the earth, and in the presence of water raised to a considerable temperature, thus allowing the respective minerals to crystallise more or less perfectly from the magma formed.

By the term **magma**, it is implied that at depths below the surface the rocks existing, whatever their origin may have been, are raised to such a temperature that, were they on the surface, they would fuse; but being under the pressure of the overlying strata they are unable to expand, and so fusion is prevented. But in the presence of water, which appears to occur to every depth it has yet been possible to explore, the heat probably effects a partial solution, and in the digester thus existing, a more or less pasty mass is formed, from which the minerals crystallise in a consecutive order.

The fact that of the minerals which constitute granite, the felspar and mica, both more fusible than quartz, occur as crystals; whilst the quartz forms a crystalline paste, which is always moulded around them, is in itself a proof that the rock could not have solidified from a state of mere fusion; moreover, the enclosure of a number of microscopic particles of water in the quartz of granite appears to indicate that, in some cases at any rate, water must have been present at the time of its formation.

The trappean rocks, as they were called by the older geologists, form a convenient field-group of rocks of medium crystalline grain, occurring in dykes and sheets. Most dolerites and diabases come under this head.

TABLE OF ERUPTIVE ROCKS.

CHARACTER.	NAME OF ROCK.	Orthoclase or Sanidine.	Plagioclase.*	Hornblende.	Augite.	Magnetite or Tit. Iron.	Quartz.	Olivine.	Vitreous Matter.	Mica.	REMARKS.
Hydro-thermal.	Granite,	×	...	...	...	...	×	...	...	×	
	Syenite,	×	...	×	...	...	...	...	...	...	
	Quartz diorite,	...	×	×	...	...	×	...	...	...	
	Diorite,	...	×	×	...	...	...	...	...	...	
	Gabbro,	...	×	...	×	×	...	...	...	...	With diallage or augite.
Trappean (rocks of intermediate grain).	Quartz porphyry (Elvan, &c.),	×	...	...	...	...	×	...	...	...	Quartz crystals.
	Fine grained syenite,	×	...	×	...	...	...	...	...	...	
	Fine grained diorite,	...	×	×	...	...	...	...	...	...	
	Dolerite,	...	×	...	×	×	...	×	...	...	Distinctly crystalline; some are volcanic.
	Diabase,	...	×	...	×	...	...	...	...	...	Some are volcanic.
Volcanic.	Rhyolite,	×	...	×	...	...	×	...	×	...	With hornblende, augite, or mica.
	Trachyte,	×	...	×	...	...	...	...	×	...	With hornblende, augite, or mica.
	Hornblende-andesite,	...	×	×	...	...	...	...	×	...	
	Augite-andesite,	...	×	...	×	...	...	...	...	...	
	Anamesite,	...	×	...	×	×	...	×	...	...	Finely crystalline.
	Basalt,	...	×	...	×	×	...	×	...	...	Compact.
Glassy (usually volcanic).	Pitchstone,	...	...	...	...	...	...	...	×	...	
	Tachylyte,	...	...	...	...	...	...	...	×	...	
	Perlite,	...	...	...	...	...	...	...	×	...	
	Obsidian,	...	...	...	...	...	...	...	×	...	
	Pumice,	...	...	...	...	...	...	...	×	...	

* Plagioclase includes all those felspars in which the two principal cleavage planes are not at right angles to one another; they contain lime, soda, or both, in their composition. Orthoclase is a potash felspar with rectangular cleavages.

Volcanic rocks are those which have reached the surface, either through volcanoes or simple fissures, and have been distributed as lava streams or as volcanic dust, &c.; they have very marked differences in structure, dependent upon their chemical composition. The **trachytes** contain a large proportion of silica, and are generally of a grey colour; they consist of hornblende and sanidine, which is a transparent variety of orthoclase. It must be remembered that in true trachytes *no free quartz* occurs, and that when quartz crystals are developed, or when there is an excess of silica in the glassy ground, the rock becomes a **rhyolite.** On the other hand, there is a series of basic volcanic rocks in which the percentage of silica is not high, and these are known collectively as **basalts.** Basalt consists of augite and magnetite, with a certain quantity of one of the triclinic felspars, and, generally, olivine; these rocks are named basalt, anamesite, or dolerite, according as they are fine grained, of medium, or distinctly crystalline structure. There is also a series of intermediate rocks between trachytes and basalts, known as **andesites,** in which the hornblende-andesites consist of hornblende and a triclinic felspar, and are allied to the diorites; whilst the augite-andesites are very closely allied to the basalts, but contain more silica in their composition.

Sedimentary Rocks.

The **mechanically** formed sedimentary rocks consist of mud, clay, sand, and gravel, together with their corresponding shales, slates, sandstones, and conglomerates, which have been produced by consolidation of the sediments. They are also at times changed, by a process of metamorphism, analogous to what takes place in the formation of granite, to schists, gneiss, or quartzite.

The **organically** formed rocks comprise limestones and coals, the former being produced by the accumulation of the shells of molluscs, &c., which have extracted lime from the water to form their covering; the latter, by the growth, decay, and submergence of trees and plants. Besides these, certain beds, such as gypsum, magnesian limestone, and rock salt, have been precipitated from solution in inland waters, such as the Dead Sea, or Great Salt Lake of Utah.

Movements of the Rocks.—These varied rocks which have either, as the sedimentary deposits, been formed under water, or, as the eruptive rocks, intruded through other beds at all times during the geological history of the Earth, have, since their

formation, been subjected to numerous changes. Some have been raised from the sea without being tilted to any extent from their original horizontal position; others have been folded into most fantastic shapes; and others again have been completely inverted. In other cases, movements which have taken place since the rocks became solidified have caused fractures, and by the rocks on one side of the crack sliding on those on the other, **faults** have been produced.

Without entering into any of the theories which have been propounded to account for these movements, it may be stated that, even at the present day, great and important movements of the land are continually taking place; in some parts the land is slowly rising from the sea; in others, a continued but gradual subsidence is going on. Earthquakes, moreover, produce slight oscillations of the land, and thus a redistribution of the land and sea is in constant progress.

There is ample evidence, in the occurrence of fossiliferous rocks which enter into the structure of important mountain ranges, that these oscillations of the land have also occurred in the past, and the varying angles at which the different sedimentary rocks are lying show that in many cases they must have been subjected to a lateral pressure, which has produced the crumpling of the rocks already referred to, and, in some cases, the dislocations or faults which have also been mentioned.

Where the rocks have been folded in the form of an arch, they are said to form an **anticlinal**; and where they occupy a basin, they are spoken of as forming a **synclinal**. Widespread folds of the foregoing nature are called **ge-anticlinals** and **geo-synclinals** respectively; and it is interesting to note that in the areas occupied by ge-anticlinals the rocks are generally so much broken and jointed that they offer great facilities for removal by the ordinary denuding agents; hence it is hardly to be wondered at that ge-anticlinals generally occupy valleys and depressions on the present surface of the earth. Not only is this the case with large structural movements, but the ordinary anticlines and synclines, which are of more local character, are found to exhibit the same peculiarity; for the synclines generally constitute the hills, while the anticlines occupy the valleys.

Geological Observations in the Field.—While it is not necessary for the prospector to make accurate geological surveys of the country on which he is engaged, it is very often of importance for him to obtain some idea of its structure; as upon

this may frequently depend the value, or otherwise, of special areas to which he may be inclined to devote his attention. More especially in stratified deposits, such as coal, is this of importance; but, even when dealing with lodes, it is frequently useful to study the distribution of the rocks in order to discover what effect those of different nature exert upon the mineral deposits.

In examining the surface of a country in which the rocks are of sedimentary origin, it will be found, as a rule, that the beds are inclined at varying angles to the horizon, and in making a geological survey of any special district it is necessary to note the **dip** and **strike** of the rocks at every available point. When any well-marked bed occurs, such, for instance, as a seam of

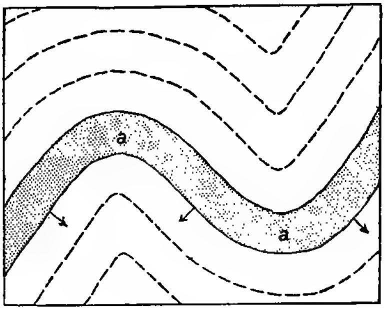


Fig. 1.—Plan.

coal or belt of conglomerate or limestone, its line of outcrop should be carefully followed and mapped; the boundaries of any eruptive rocks should also be clearly delineated on the plan.

The **strike** of a rock is the direction of a horizontal line in any of the beds; or, in other words, the direction in which a level drive would be put in on the floor of the bed. The **dip** is a line at right angles to the strike on the plane of the beds, and the angle is to be measured in relation to the horizon.

When any particular bed is followed on the surface, it is often found that it does not continue with the same strike for any great distance; that, in fact, it gradually veers round, as shown at (*a*) in the sketch, the direction of the dip changing at the same time. By a study of a plan thus made the positions of the anticlines and synclines can be determined, and other lines of elevation can also be noted; and a section constructed,

such as the following, which serves to convey a very fairly accurate conception of the structure of the country. As a matter of fact, the boundaries of rocks are sometimes rather obscure in consequence of the variable movements which have occurred; but the occurrence of faults and dykes is what makes this tracing of boundaries on the surface most difficult. The

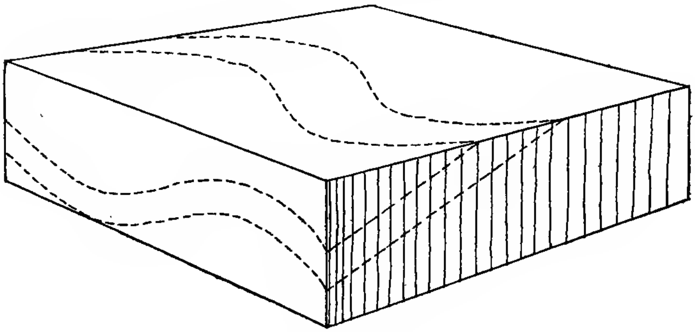


Fig. 2.—Section.

displacements due to faults may be only an inch or so, or may be several hundred feet; while in a few exceptional cases, as, for instance, in the fault which crosses Scotland from Dunbar to the Ayrshire coast, the displacement may be as much as two or even three miles.

A study of faults is of very great importance, more especially on account of their close association with mineral lodes; but faults should never be assumed for the purpose of explaining difficulties which are encountered in mapping the surface geology, unless very good evidence of their existence can be found, and until every other means of explanation of the phenomena has been tried and found wanting.

CHAPTER II.

THE DETERMINATION OF MINERALS.

The determination of the more important minerals which may be met with deserves special attention at the outset of the subject, and the present chapter will be devoted to the simpler means of distinguishing them. It is not, however, intended to encroach upon the detailed study of mineralogy, on which subject the many valuable treatises published can be consulted.

When minerals occur in a sufficiently pure state, they are generally crystallised more or less perfectly, in certain definite forms—*e.g.*, *pyrites*, *calcite*, and *garnet*—but many minerals, especially those forming sedimentary rocks, are composed of very minute grains, in which either the crystalline form has been imperfectly developed or the minerals are altogether amorphous—*e.g.*, *earthy limestone*, *coal*, and *massive pyrites*. A few are incapable of crystallisation—*e.g.*, *amber* and *limonite*.

Mineralogy treats only of natural inorganic substances which have the same composition throughout; but rocks, which may be composed of several minerals, either crystallised or not, sometimes exhibit on a large scale regular forms, which must not be considered as due to crystallisation, but to the process of cooling; or to cooling and drying, and the consequent contraction. Compact basalt, for instance, which has been formed in a molten state, is frequently divided during cooling into more or less regular prisms, which are often six sided; and some of the extensive beds of gypsum near Paris have, in drying, assumed the form of huge prismatic pillars.

There are certain physical properties of minerals which are of importance in their determination, regarding which a few notes will be of interest.

Structure.

When minerals do not occur either in isolated crystals or in distinct groups, but consist of aggregated crystalline or compact particles, they affect different kinds of structure; and this struc-

ture, besides assisting in the determination of minerals, is of economic importance; for on it depends the value of certain minerals for ornamental purposes.

Granular Structure, of which sandstone may be taken as a type, is produced by more or less rounded grains being cemented together. A coarse granular structure is best seen in chrome iron-ore, in which the grains, since they are not cleavable, can be noticed at once. Galena and zinc blende are often more or less granular; but, since both these minerals cleave readily, the fracture is lamellar when the grain of the ore is coarse. If, however, they are fine grained, these, in common with many other ores—*e.g.*, *copper glance*, *cinnabar*, *pyrrhotine*, and, more rarely, *enargite* and *stibnite*—exhibit a fine granular structure, and are sometimes so fine grained as to approach more or less perfectly to a compact texture.

Saccharoid Structure.—When the mineral is composed of small crystalline grains, showing facets and cleavages, the structure is called **saccharoid**—*e.g.*, *statuary marble* and *alabaster*.

Lamellar Structure.—When the crystalline particles are minute and flat, being laid one on the other, the structure is termed **scaly**—*e.g.*, *chlorite;* while a true **lamellar** or **laminar foliated** structure, which is best seen in *talc* and *mica*, also exists in *molybdenite*, and more rarely, and in a less perfect manner, in *nickel glance*.

Capillary structure is best illustrated by *asbestos*, the fibres of which are readily separable; but a similar structure may be noticed in some specimens of *millerite*, the fibres being easily separable, but small, brittle, and generally radiating. Only a few other minerals possessing this structure could be mentioned, and an equally small number occur in velvet or tuft-like excrescences.

Fibrous structure is the term employed to describe those minerals in which the fibres cannot be easily separated, and is generally to be observed in minerals crystallised in a lode perpendicular to the walls of the fissure; but is sometimes developed parallel to the walls, or even in radiating groups. In the first two cases the fibres are straight, as in *chrysotile*, which forms small veins in serpentine, and is only a variety of serpentine itself; and again, in *calcite* and *gypsum*, two minerals which sometimes exhibit this structure, but do not ordinarily possess it; both fibrous calcite and fibrous gypsum have been called *satin-spar*, and are cut as ornaments. The fibrous radiate structure is conspicuous in *malachite*, *wood tin*, and some

hæmatites; is well marked in stalactites of *calcite, barytes,* and *calamine,* while *göthite, spherosiderite,* and *apatite* may also be mentioned as occurring in radiating fibrous forms. Minerals possessing this radiate structure are often called "concretions," but many concretions consist of concentric layers where there is no sign of crystallisation, and must, therefore, be distinguished from those in which crystallisation exists.

Radiate Structure is not only found in minerals formed of minute needle-shaped crystals, but stout prismatic crystals with pyramidal ends are sometimes arranged in radiating groups, as in the case of *amethyst quartz* when crystallised in vughs or cavities in rocks or lodes. *Pyrites* also, and *azurite,* when found in balls which have crystallised in a semi-liquid mud, exhibit the above structure. When radiating crystals assume a slender prismatic form they diverge from one another, sending their needle-shaped projections in every direction around the centre, like spines on a sea urchin; *pyrolusite, stibnite,* and *natrolite* occur in such forms.

Bacillary Structure is the term used to describe those minerals which occur grouped in bundles like sticks—*e.g.*, *Epidote.*

Dendritic Structure.—Where many crystals are attached one to the other, like beads in a necklace, and especially where these diverge like the branches of a tree, they are called **dendritic.** Native copper, silver, and gold frequently occur in this form, and oxides of iron and manganese are often found in the joints of rocks crystallised in the most beautiful fern-like forms.

Concretionary Structure is affected by uncrystallised minerals which have grown from a centre in concentric layers; and may also be seen in certain rocks—*e.g.*, *basalts, sandstones,* &c., in which decomposition has taken place around centres. Where nodules have grown around a centre in mud or loose sand, the form is spherical or nearly so. Many valuable ores of iron occur in spherical forms; extensive deposits (oolitic iron) formed entirely of small grains occur in the Jurassic system of Europe; pisolitic ores, in which the grains are the size of a pea, are found in the Tertiary rocks, and similar ores also occur in serpentine. In the Jurassic system, oolitic limestones composed of small perfectly round grains of carbonate of lime occur, and a similar structure is developed in the calcareous sand on the shores of the Great Salt Lake at Utah.

The centre of these nodules is sometimes formed of a mineral grain, and very often of a fossil plant, fish, or shell. In slaty rocks the nodules are flattened and irregular in shape, and are sometimes mistaken for fossils.

Mammillary Structure.—When concretions have been formed at the same time around several centres, which are at regular distances apart, a mammillary structure is induced—*e.g.*, *chalcedony*, which is very variable in form and size; different modifications are described as **botryoidal** (like a bunch of grapes), **reniform** (kidney-like), &c.

Nodules of ironstone with fossil fish occur in the Carboniferous and Permian systems of Europe, and nodules of cement stone in the Cretaceous rock of New Zealand. When deposition takes place around a stick, the concretion has the form of a cylinder, this structure being very common in some bog iron ores; and earthy cobalt ores are found under the same conditions in New Caledonia, where they occur in a decomposed diorite associated with serpentine, and have accumulated around the roots of existing trees. Concretions of manganese ore are also formed in the depths of the sea.

Vitreous Structure.—When minerals exhibit no sign of crystallisation they are called **amorphous**; and some which do not possess the power of crystallising can be distinguished as having a **compact** or **vitreous** structure—*e.g.*, *amber*.

Cleavage.

Crystallised minerals have a tendency to split more readily in some directions than in others; this property is termed **cleavage**. In some minerals the cleavages are so easy that, in transparent varieties, the planes of cleavage can be seen through the crystals, this being often the case in *Iceland-spar*, *orthoclase*, and *barytes*.

In the cube and rhombohedron, in which the faces are all of the same shape, there are three directions of cleavage parallel to the sides—*e.g.*, *galena* and *rock-salt* in the cube, and *calcite*, *dolomite*, and *siderite* in the rhombohedron. These cleavages are very apparent and are good characters for recognition of these minerals.

The most useful instance of cleavage is that which occurs in the diamond, in which there is an easy cleavage parallel to the sides of the octahedron; advantage is taken of this property in shaping diamonds for cutting. If the blade of a knife is applied in the proper direction, a smart blow will effect the cleavage.

In six-sided prisms there is an easy cleavage parallel to the base in some minerals—*e.g.*, *beryl* or *emerald* and *apatite*.

In the rhombic prism there is also frequently an easy cleavage parallel to the base—*e.g.*, *topaz* and *talc*. *Barytes*, which crystal-

lises in modified rhombic prisms, has two easy cleavages parallel to the sides of the prism, and one parallel to the base.

In the oblique prisms of *orthoclase* there are two easy cleavages, one parallel to the base and another at right angles to the first and parallel to the oblique diagonal. They are at right angles to one another, hence the name of the mineral.

Cleavage is also a property of certain rocks—*e.g.*, *slates*—and is most perfectly developed in roofing slates of good quality. In quarrying sandstones advantage is taken of the joints of the rock to divide it into building stones and slabs of different thickness, which have subsequently to be dressed on the sides as required; but these properties of jointing and cleavage in rocks are of quite different origin from the cleavage of minerals, being due entirely to stress or pressure in various directions after the consolidation of the rocks, and have no relation whatever to the composition of the rocks, whereas, cleavage in minerals is a structural peculiarity, which is constant in certain mineral species.

Lustre.

The term **lustre** is employed by mineralogists to describe, with certain adjectives, the brilliancy or gloss of any substance. In describing the lustre, well-known substances are taken as the types, and such terms as **adamantine lustre** (diamond-like) and **vitreous lustre** (glassy) are used. When minerals do not possess any lustre at all they are described as "dull." The lustre of a mineral is quite independent of its colour.

The terms usually employed to describe the lustre of minerals are as follows:—

1. Metallic.	5. Resinous.
2. Semi-metallic.	6. Greasy.
3. Adamantine.	7. Nacreous.
4. Vitreous.	8. Silky.

These terms are purely arbitrary for, although a plate of polished silver may be taken as the best type of metallic lustre. this is also exhibited by all the metals irrespective of their colour, and by most metallic sulphides, such as *pyrites*, *stibnite*, &c.; hence no distinct line can be drawn between those minerals possessing a metallic lustre and those coming under the sub-metallic group, of which *diallage* and *anthracite* may be taken as types.

The lustre of minerals will frequently vary—

(*a*) As they are more or less impure.

(*b*) As other physical properties vary.

In illustration of the first class of variations, window glass may be taken as the type of vitreous lustre; but glass can be made to exhibit a lustre approaching that of the diamond, mother of pearl, opal, &c., by the admixture of certain chemical substances. Something approaching an adamantine lustre can be imparted to glass by lead, and the same effect can also be obtained, although with greater intensity, by substituting the rare metal thallium, which is very closely allied to lead in its chemical properties. Very good imitations of the diamond are made in this way, which are sometimes difficult to detect by a superficial examination.

The second class of variations may be illustrated by *gypsum*, which has a vitreous lustre when crystallised, but a silky lustre when fibrous.

Many minerals possess a different lustre on different faces; *pyrosmalite*, for instance, which crystallises in the form of a six-sided prism, has a semi-metallic lustre on the sides, while the ends are greasy or nacreous.

Calcite and gypsum are vitreous on some faces, and nacreous on others; and the same may be said of celestine, orpiment, and orthoclase.

The lustre of minerals may be taken advantage of for the first subdivision in a scheme for recognition; and for this purpose it is only necessary to divide them into those which have a metallic lustre and those which no not possess this property.

Metallic and Semi-Metallic Lustre.—The first term needs no definition; all metals in the native or pure state, and especially the noble metals, exhibit this quality in the highest degree, and are, indeed, so bright when polished that they can reflect images perfectly. Some sulphides have a perfect metallic lustre, and iron pyrites was formerly used by the Indians of South America to make their mirrors. All metallic sulphides have a metallic lustre, with the exception of zinc blende and cinnabar, which are adamantine; although some black varieties of zinc blende containing much iron might be described as metallic-adamantine; and hauerite (sulphide of manganese), which has but an imperfect metallic lustre.

Without Metallic Lustre.—This group includes a large number of minerals, many of which are of commercial value; and it will be well at this point to call attention to those which possess an adamantine lustre. Of these, the diamond affords the most perfect type of adamantine lustre, although other well-known minerals can also be considered as good illustrations—*e.g.*, *cassiterite* when in pure and shining crystals, *zircon*, and

cerussite. It may be well to again reiterate the fact that colour has nothing to do with this property of lustre.

Most minerals whose lustre is adamantine are very heavy; the diamond is lightest—sp. gr. 3·5; then *octahedrite*, *blende*, and *göthite*—sp. gr. about 4. Between 4 and 5 sp. gr. another variety of titanic acid called *rutile* and also *zircon* occur; between 5 and 6 sp. gr. *valentinite*, *cuprite*, *embolite*, *pyrargyrite*, and *proustite* are found; between 6 and 7 sp. gr. *crocoisite*, *cerussite*, *anglesite*, and *wulfenite*—all of which are lead minerals; these and *calomel*, or chloride of mercury, have an adamantine lustre; and between 7 and 8 sp. gr. may be noted *cassiterite*, or oxide of tin; *mimetite*, and *pyromorphite*—both of which are lead minerals; *wolfram*, or the tungstate of iron and manganese, and *cinnabar*. A few of these—*e.g.*, *rutile*, *pyrargyrite*, and *wolfram*—have a metallic adamantine lustre.

Out of the twenty minerals mentioned above as possessing an adamantine lustre, the diamond is the only non-metallic mineral; the remaining nineteen are metallic, and of these

6 are	compounds of	lead,
2 ,,	,,	silver,
2 ,,	,,	mercury.

The remarkable property possessed by lead of imparting an adamantine lustre to minerals and artificial products is well known, and is taken advantage of in the imitation of precious stones, but the greater the proportion of lead employed, the softer is the glass formed.

Colour.

The colour of minerals may be due to four different causes; but in some cases it is difficult to say to which of these groups coloured minerals belong.

Group 1.—Those in which the colour of a mineral is that which it would possess when pure, or when artificially formed.

Group 2.—Those in which the colour is due to the mixture of substances crystallising in the same form, and replacing one another in the composition of a mineral.

Group 3.—Those in which the colour is due to a small quantity of colouring matter, dissolved in a mineral, by which its chemical composition is not greatly affected.

Group 4.—Those in which the colour is due to a mechanical mixture of substances, which are not dissolved in the mineral, but can easily be distinguished on microscopical examination.

In this group are included those minerals whose colours are due to mere impregnation.

Group 1.—The first group can be illustrated by the following examples :—

Black.—Graphite, coal, and black oxide of copper.

Blue.—Azurite and lapis lazuli.

Green.—Malachite, libethenite, dioptase, atacamite, nickel ochre, texasite, and bromargyrite.

Yellow.—Sulphur, amber, orpiment, and wulfenite.

Orange.—Realgar.

Red.—Cuprite, pyrargyrite, cinnabar, red ochre, and red hæmatite.

Pink.—Erythrine, diallogite, and rhodonite.

White or Colourless.—Nearly all the alkaline and earthy minerals when pure—*e.g.*, barytes, gypsum, calcite, meerschaum, cryolite, and quartz.

It will be seen that nearly all coloured minerals of the first group are metallic, although none are included in the above list whose lustre is metallic; they are, with few exceptions, anhydrous oxides of the metals, metallic sulphides, antimonides or arsenides.

A few minerals possess a metallic lustre and characteristic colour, as follows :—

Violet to Copper Red or Violet Brown.—Erubescite or bornite.

Indigo Blue (semi-metallic).—Covelline.

Greenish Grey.—Tin pyrites.

Brass Yellow.—Millerite and copper pyrites.

Copper Red.—Native copper.

Light Copper Red.—Nickeline, breithauptite.

Reddish Silver White.—Cobaltine.

Reddish Brown (due to tarnish; normal colour on fracture, tin white to steel grey).—Domeykite.

Yellowish Brown to Copper Red.—Pyrrhotine.

Violet Brown.—Nickel pyrites, sternbergite.

Brown Black.—Hauerite.

Group 2.—The most common instances of colour due to the interchange of isomorphous substances are those of the carbonates of iron (*siderite*), of manganese (*diallogite*), of lime (*calcite*), and of magnesia and lime (*dolomite*). The two first are coloured, while the other two are colourless or white; but, since they can replace one another in any proportion, *siderite*, which is yellowish,

and *diallogite*, of a fleshy colour, will impart a shade of colour to *calcite* or *dolomite* when combined with them.

Kerargyrite and *bromargyrite* are also isomorphous; the first is grey in colour, the second dark green; and mixtures of the two, or chlorobromides of silver termed *embolite*, &c., are of all shades from grey to dark green, according to the relative proportions of chlorine or bromine they contain.

GROUP 3.—Very little seems to be known of those substances, a very small proportion of which at times impart bright colours to minerals. The colour so derived may be described as accidental, since the trace of colouring matter does not greatly affect the chemical composition of the mineral, and in this class may be included all the gems. *Diamond*, which is colourless when quite pure, is occasionally red or blue, and then attains a fabulous value; but is more frequently yellowish, brown, or black. Corundum is commonly blue (*sapphire*), red (*ruby*), more rarely yellow (*oriental topaz*), and still more rarely green (*oriental emerald*) or violet (*oriental amethyst*).

Topaz is colourless, yellow, or light blue. Emerald, beryl, and aqua marine are the same species, but the first is of a rich deep green and the others of a pale bluish-green colour. The colouring matter of the emerald is still uncertain, for, although some analysts are said to have found chromium present, the emerald loses its colour at a red heat, at which temperature oxide of chromium should not be destroyed; this seems to suggest an organic matter as the colouring agent.

Quartz, which in its pure state is colourless, often occurs milky, smoky, or black, more rarely yellowish (citrine quartz), imitating topaz or violet (amethyst). A crystallised variety from Spain is hyacinth red, and a compact variety pink.

Amongst minerals other than gems three are most remarkable on account of the different colours they assume, these are fluor-spar, apatite, and rock-salt. Fluor-spar and apatite occur in nearly the same shades of colour, ranging from colourless to white, pink, red, yellow, green, blue, violet, and the intermediate hues. Rock-salt is found colourless, white, red, yellow, and blue.

A variety of orthoclase, remarkable for its apple-green colour, is found in Siberia and Colorado. The colouring substance is still unsettled, although stated by some to be copper.

It is not always easy, or, indeed, possible, to draw a clear line between the coloured minerals of Groups 2 and 3. If the most notable groups of the silicates be taken—*e.g.*, the hornblende, augite, garnet, epidote, and tourmaline groups—it is found in

each that, while all the minerals composing the group obey the same laws of crystallisation, and only vary in composition within certain limits, the minerals are white, colourless, or highly coloured, according to the proportion of colouring matter, chiefly oxides of iron, manganese, and chromium, present. In the hornblende group there are white, or nearly white, varieties (*asbestos* and *tremolite*), which do not contain iron; an intermediate variety (*actinolite*), which contains a small quantity of iron, is green; and a third variety (*hornblende*), which contains a large proportion of iron, is black, or nearly black.

In the augite group there is a variety (*diopside*) which is generally transparent, colourless, or pale green, and contains only traces of iron; while two other varieties are nearly black, and contain large proportions of iron and manganese.

In the garnet group there is a variety (*grossularia*) which is white or very pale green, and contains very little iron; a red variety (*almandine*), used as a gem, and containing much iron; a black variety (*melanite*), also containing much iron; and a green variety (*uwarowite*), containing much chromium.

In the tourmaline group the substances which impart colour are more difficult to determine precisely. Those containing much iron are brown or black; the green contains iron and manganese; the red contains manganese and no iron; and the colourless contains no iron, and only a trace of manganese. All the colourless and light-coloured red and green varieties also contain lithia.

Group 4.—The substance which most frequently colours rocks and minerals mechanically is oxide of iron, imparting a brownish or red colour to earthy-looking minerals and rocks, and it is to this also that the yellowish and reddish colours of some sandstones and limestones, used for building purposes, is due; although, in some marbles, the colour is said to be derived from organic matter.

The nickel ore of New Caledonia, which consists of silica, magnesia, and oxide of nickel, seems to be, in some varieties at least, only silicate of magnesia impregnated with oxide of nickel. In some mines the silicate of magnesia exists nearly or quite free from nickel, and of a pure white colour, whence it passes through all shades to the richest green. Some specimens under the microscope show the green oxide of nickel disseminated in grains through the white silicate of magnesia.

In some cobalt and nickel mines in Germany stalactites of carbonate of lime are coloured pink by a mechanical impregnation of arseniate of cobalt.

The silicates and carbonates of zinc are white when pure, but the presence of iron as a mixture often gives them a yellow colour; and calamine, when blue, is coloured by copper.

Hardness.

The hardest substance known in nature is the diamond; all other minerals can be scratched by it. Between this and the softest—*e.g.*, *talc* and *horn-silver*—certain minerals have been chosen to form a series called the **scale of hardness**, which is of great use in the determination of minerals. It need hardly be added that the true hardness of a mineral is that which it exhibits when approximately pure, and is best tested in crystallised varieties.

Scale of Hardness.

1. Talc } Scratched by the nail.
2. Gypsum }
3. Calcite }
4. Fluor-spar } Scratched by steel of ordinary hardness.
5. Apatite }
6. Orthoclase—Scratched by well tempered steel—not by window glass.
7. Quartz.
8. Topaz.
9. Corundum.
10. Diamond.

In descriptive books of mineralogy the hardness of minerals is always expressed by numbers; thus, *chromite* H. 5·5, signifies that this mineral will scratch apatite, but can be scratched by orthoclase.

Some precautions are necessary when testing the hardness of any mineral. The scratch should be made on a smooth clear surface and with a sharp edge or angle of the scratching mineral. It often happens, if the mineral experimented upon is the harder, that, instead of a scratch, a line of dust is left on its surface. This should be carefully wiped away, when it will be easily seen that no scratch has been produced on the harder mineral, and that the edge of the other has been blunted. This is what would happen if an attempt were made to scratch topaz with quartz or corundum with topaz.

Streak.

In testing the hardness of minerals another character of importance—viz., the streak or colour of the dust formed when a mineral is either scratched or powdered, may be observed.

TABLE SHOWING COLOUR AND STREAKS OF METALLIC MINERALS.

Colour of Mineral.	Colour of Streak.									
	Cherry-red.	Red-brown.	Brown-black.	Black.	Iron-black.	Greyish-black.	Steel-grey.	Blackish lead-grey.	Tin-white.	Silver-white.
Red-brown,	...	...	Wolfram	...	...	...	...	...	...	...
Brown-black,	...	Hausmannite Grey copper	Braunite	...	...	...	...	...	...	...
Iron-black,	Hæmatite	Manganite	Wolfram	Magnetite Pyrolusite Polybasite Enargite	Stephanite Polybasite	...	...	...	...	...
Dark steel-grey,	...	Hæmatite	...	Psilomelane Grey copper	...	...	...	...	...	...
Steel-grey,	Pyrargyrite	...	...	...	...	Gersdorffite	Bournonite	...	...	...
Light steel-grey,	...	...	...	...	...	...	Freieslebenite	...	...	...
Black lead-grey,	...	...	...	...	...	...	Argentite	...	...	...
Lead-grey,	...	Tennantite (red grey)	...	Stromeyerine Copper glance	...	...	...	Galena Stibnite Bismuthine	...	...
Light lead-grey,	...	...	...	...	...	Mispickel	...	...	...	...
Tin-white,	...	...	...	...	...	Smaltine	...	...	Antimony	...
Silver-white with reddish hue,	...	...	...	...	...	Cobaltine	...	...	...	Bismuth

A few minerals which are malleable—*e.g.*, *copper glance* and *silver glance*—as well as the malleable metals themselves, instead of giving a dust when scratched afford a shining streak. The streak, however, of most minerals is of a lighter colour than the mineral itself.

A certain number of minerals with metallic or semi-metallic lustre are difficult to distinguish by their mere appearance, their colour ranging from silver-white to iron-black. For a discrimination of these their streak is frequently of value, and the preceding table will be of service in distinguishing them.

Regarding these it may be noted that *stibnite* frequently has a blackish tarnish, *bismuthine* and *domeykite* have a yellowish iridescent, *smaltine* has sometimes a greyish iridescent tarnish, while *gersdorffite* and occasionally *galena* are tarnished grey or greyish black. *Polybasite* in small crystals is red by transmitted light and the dust of *enargite* has a metallic lustre. Among the softest minerals a few are malleable like wax—*e.g.*, *ozokerite* and *horn-silver;* whilst others are composed of particles or lamellæ so slightly cohesive that they separate when either touched or rubbed, and soil the fingers more or less readily—*e.g.*, *molybdenite*, *earthy manganese*, *red* and *yellow ochres*, *steatite*, *graphite*, &c.

Flexibility and Elasticity.

Some minerals can be easily bent without breaking—*e.g.*, *talc*, *mica*, *chlorite*, *molybdenite*, *native silver*, &c. Those that, after being bent, can resume their former shape like a steel spring are called *elastic*—*e.g.*, *mica*, and *elaterite*. A remarkable instance of flexibility, even combined with elasticity, amongst the rocks is that of a micaceous sandstone from Brazil called *itacolumite*, which is the matrix of the diamonds there.

Malleability.

Malleable substances can be hammered out without breaking, and it is on this quality that the value of certain metals in the arts depends—*e.g.*, *copper*, *silver*, *gold*, *lead*, *iron*, &c.

A few are malleable and at the same time sectile, that is to say, can be cut with a knife—*e.g.*, *silver glance*, *horn-silver*, and *ozokerite*.

Mineral caoutchouc (*elaterite*) is sectile, but, like india rubber, can only be shaped when hot. The elasticity of elaterite is so characteristic that the mineral will be readily recognised.

Ductility or the capability of being drawn into wire is a property which is confined exclusively to certain metals. It is

possessed by gold in the highest degree, since that metal can be drawn into the finest wire or rolled into leaves of such fineness that 30,000 of them are not thicker than an eighth of an inch.

Smell.

A few minerals only, like bitumen, have a strong smell, which is readily recognised; but specimens generally require to be struck with a hammer, rubbed or breathed upon, before any smell can be observed. Some black limestones have a bituminous odour, while some have a sulphurous, and others a fœtid smell; hydraulic limestone has a smell of clay, which can be detected when the mineral is breathed on. Some minerals containing much arsenic—*e.g.*, *mispickel*—smell of garlic when struck with a hammer.

Taste.

Only soluble minerals have any taste, and this can only be described by comparison with well-known substances—*e.g.*, **acid**, vitriol; **pungent**, sal-ammoniac; **salt**, rock-salt; **cooling**, nitre; **astringent**, alum; **metallic astringent**, sulphate of copper; **bitter**, sulphate of magnesia; **sweet**, borax.

Specific Gravity.

Prospectors soon acquire some proficiency in testing the weight of minerals by handling them, and a little practice with well-known substances will enable them to class most minerals within certain broad limits by this system of observation. The specific gravity of a mineral is its weight compared with water at standard temperature and pressure, which is taken as the standard, and described as having a specific gravity of 1; consequently, to determine that of a mineral it is necessary to find the weight of a piece of the mineral and that of a corresponding bulk of water, and to divide the first by the last.

This can be done with great accuracy in the laboratory, where delicate balances are available, but is not applicable in the field, when the most that can be undertaken is to class minerals roughly within certain broad limits, and, indeed, this is frequently sufficient for the prospector. A rough classification of minerals under three groups is as follows, the arrangement being consecutive from the lightest to the heaviest. This list does not include

all the minerals mentioned in this book, but may be taken as a scale which will serve for purposes of comparison with other minerals :—

Group 1.—Specific Gravity less than 3·5.—Amber, bitumen, lignite, coal, natron, sal-ammoniac, borax, Epsom salt, anthracite, potash alum, copperas, saltpetre, sulphate of zinc, sulphur, nitrate of soda, chabazite, graphite, sulphate of copper, rock salt, opal, gypsum, harmotome, quartz, orthoclase, lapis lazuli, serpentine, beryl, emerald, vivianite, cordierite, albite, anorthite, labradorite, alunite, talc, steatite, calcite and marble, cryolite, dolomite, magnesite, aragonite, mica, fluor-spar, tourmaline, turquoise, anhydrite, nephrite (*jade*), apatite, andalusite, calamine, epidote, hornblende, augite.

Group 2.—Specific Gravity between 3·5 and 8·5.—Topaz, diamond, olivine, diallogite, realgar and orpiment, spinel, pleonaste, strontianite, chrysoberyl, rhodonite, azurite, spathic iron, limonite, blende, celestine, garnet, gœthite, corundum, malachite, copper-pyrites, psilomelane, brookite, rutile, willemite, smithsonite, witherite, manganite, tennantite, chromite, tin pyrites, molybdenite, magnetic pyrites, barytes, stibnite, zircon, hausmannite, braunite, pyrolusite, pyrites, magnetite, tetrahedrite, hæmatite, kerargyrite, proustite, arsenic (*metallic*), bornite, pyrargyrite, mispickel, cobaltine, cuprite, gersdorffite, anglesite, stephanite, tellurium, pitchblende, cerussite, bismuth glance, antimony (*metallic*), chloanthite, smaltine, tinstone, bismuthite, argentite, wolfram, nickeline, galena, cinnabar.

Group 3.—Specific Gravity over 8·5.—Copper, bismuth, silver, mercury, electrum, gold, platinum, iridium.

A rough idea of the specific gravity of minerals can be arrived at by washing in the tin dish, and this process, which is understood by every prospector, and in whose hands it can be made to yield the best results, will give sufficiently accurate results for the determination of the most common minerals. In all processes of ore concentration, based on specific gravity, the larger stones are separated mechanically at the outset, and the grains of sand, in which the final concentration takes place, are of more or less uniform size. In dressing tin and lead ores this sorting is frequently effected by metallic sieves forming the bottoms of jiggers. The sorting in a tin dish is effected by picking out the larger stones by hand, but in testing the specific gravity of minerals they should be divided, in the first instance, into regular sizes by sifting. For this purpose two sieves will be sufficient, one with eight holes, the other with sixteen holes to the linear inch ; then all which will pass through the coarser sieve, but not

through the finer, will be of sufficiently uniform size for the tests required.

The lighter portions will first be separated by washing; these will consist of shale, ferruginous quartz, brown oxide of iron, pebbles of tourmaline, &c., mostly of a lower specific gravity than 3·5, and the heavier minerals which remain in the dish will be zincblende, magnetite, pyrites, hæmatite, mispickel, tinstone, wolfram, gold, platinum, &c.

By a careful manipulation of the dish in the manner generally adopted by miners when showing the gold, these heavy minerals can be easily enough separated into three groups, viz.:—gold, platinum, &c., including the minerals of group 3; tinstone, wolfram, &c., including the heavier minerals of group 2; and zincblende, magnetite, hæmatite, mispickel, &c., including the lighter and medium minerals of group 2.

Some of these minerals, mispickel for instance, can be readily recognised, and, where this is the case, those which lie up-stream and those below can be subdivided as being of greater or less specific gravity respectively than 6·3, which is the specific gravity of mispickel. Where the minerals in the dish cannot be readily recognised, a few fragments of metallic antimony or zinc, or tinstone painted white (all of which have a specific gravity of about 7), should be introduced into the dish to serve as a gauge.

Another way of dividing minerals according to their specific gravity is by means of liquids of high density, those most convenient in practice being the **Klein Solution (Cadmium Borotungstate)**, and that suggested by Brauns, **Methylene Iodide.** The former can be diluted with distilled water, the latter only with benzole. The use of these liquids is discussed in most modern text-books of mineralogy or petrology, but the most simple method of rapidly determining the specific gravity of small mineral grains, gems, &c., is undoubtedly the **Diffusion Column**, devised by Professor Sollas. A small quantity of the liquid selected, at its maximum density—say 3·3—is poured into a test-tube. A dilute solution of the same material is gently added to this, and floats upon the top. Gradually, if left for from 12 to 24 hours, diffusion takes place, and Prof. Sollas has shown that a column of liquid results, the density of which increases with regularity from above downwards. If grains of known density, such as fragments of well-selected minerals, are dropped into this column, they will float at different levels, and will act as index-points. An unknown grain, unless its density is greater than that of the lowest layer of the column,

will float at a certain level, where the liquid is of the same density as itself. Its specific gravity can be found by measuring the distance between any two of the index-grains, from which the increase of density can be determined for, say, every millimetre that we descend in the column; the vertical distance of the unknown grain above or below one of the known ones will then serve, by a simple proportion, to determine its specific gravity.

It will be seen that nearly all the metallic minerals have a specific gravity between **3·5** and **8·5**—*e.g.*, copper pyrites, chromite, pyrolusite, stibnite, iron pyrites, &c.—or are lighter than copper, which stands by itself with a specific gravity of about **8·7**.

The heavier metals and metallic minerals have specific gravities ranging from **9·5** to **19**. They are few in number, and will be easily recognised.

Lastly, the few metallic minerals in Group 1, with low specific gravities, are sulphates, carbonates, silicates, and phosphates, which contain a large proportion of oxygen, and they often contain water in combination with them. Amongst these are copperas, vivianite, dioptase, chrysocolla, azurite, &c.; none of them being compounds of minerals heavier than copper, and this for two different reasons.

In the first place, a heavy metal, such as lead, even when oxidised, will still form a heavy mineral—*e.g.*, cerussite or anglesite; and in the second, the noble metals, which are at the same time the heaviest, do not occur as oxidised minerals, but are found only in combination with sulphur, chlorine, bromine, iodine, arsenic, antimony, or tellurium.

Amongst the non-metallic minerals a few are remarkable for their high specific gravity, in consequence of which they will be found to encroach upon the metallic series.

They are all found in mineral veins, although for one of them (celestine) this is the exception. Barytes is the heaviest; its specific gravity being about 4·7, or that of stibnite. Witherite has a specific gravity of 4·3, or about that of tin pyrites. Celestine has a specific gravity equal to that of alabandine; and strontianite is nearly as heavy as carbonate of iron, its specific gravity being 3·7.

The number of minerals whose specific gravity is not superior to 3·5 is far greater than all the metallic minerals; but their importance is not so great, although they include all the combustible minerals, all the soluble minerals, and most of the earthy minerals; about half of them are silicates, all of which are rather hard.

The lighter minerals of this series are chiefly either combustible or soluble, the heaviest combustible minerals being diamond, with a specific gravity of 3·6; graphite, 2·2; and sulphur, 2.

Amongst the soluble minerals the heaviest are sulphate of iron, 1·9, and sulphate of copper, 2·2. The others are all, or nearly all, alkaline salts, the heaviest being nitre or saltpetre with a specific gravity of about 2.

Amongst the numerous class of silicates, including silica itself, the lightest is opal with a specific gravity about 2; then come the zeolites, which are hydrous silicates containing a certain proportion of the alkalies, soda, or potash, which make them very easily fusible, and all of these have specific gravities ranging from 2 to 2·3; while quartz, on the importance of which mineral it is not necessary to insist, has an average specific gravity of 2·6. Nearly all the silicates, therefore, have specific gravities ranging between 2 and 3·5; but some are heavier, such as zircon (the heaviest of the precious stones), which has a specific gravity between 4 and 4·7, and chrysoberyl with a specific gravity between 3·6 and 3·8.

It will be seen from the foregoing remarks that the division of minerals into three groups according to their specific gravity will be easily made, and will be very useful for purposes of identification.

Blowpipe Characters.

Minerals may be either hydrous or anhydrous, and consist—

1. Of elements alone; *e.g.*, native metals, *gold*, *silver*, *platinum*, &c., or *sulphur*.

2. Of combinations of the other elements with oxygen forming oxides; *e.g.*, *cuprite*, *hæmatite*, or *quartz*.

3. Of combinations of the other elements with sulphur, antimony, arsenic, tellurium, chlorine, bromine, or iodine forming sulphides, antimonides, arsenides, tellurides, chlorides, bromides, or iodides; *e.g.*, *pyrites*, *sylvanite*, *kerargyrite*, or *embolite*.

4. Of combinations of a metallic oxide, or base with an oxidised non-metallic element or acid forming carbonates, phosphates, sulphates, nitrates, or silicates; *e.g.*, *malachite*, *libethenite*, *pyromorphite*, *dioptase*, &c.

All chemical tests for minerals, whether with the blowpipe or in the wet way, depend upon some chemical change which is brought about, thus allowing the element, base, or acid to be recognised. These changes consist either of the decomposition of the mineral, or the formation of fresh compounds. The

following instances will sufficiently illustrate the character of these changes.

If the oxide of a metal, copper for instance, is mixed with carbonate of soda and fused on charcoal, the copper is reduced to a metallic state, the oxygen combines with the charcoal to form carbonic acid, which goes away as a gas, and any silica which is present decomposes the carbonate of soda to form a silicate of soda, which may be looked upon as a slag.

If a hydrous mineral is heated in a glass tube, closed at one end, the water is given off and condenses as drops in the cool part of the tube.

If an arsenical mineral—*e.g.*, *mispickel*—is heated in a closed tube a crystalline deposit of arsenic is formed in the tube; but if it is heated in the air, white fumes of arsenious acid are evolved which smell like garlic.

If a drop of hydrochloric acid be placed on a carbonate, such as limestone, the presence of carbonic acid is recognised by the effervescence which takes place, the stronger acid having combined with the lime has liberated the carbonic acid in a gaseous form. In the case of very many mineral carbonates, the acid requires to be heated for this reaction.

The discrimination of minerals will form the basis of the determination of the value of an ore; for if, by washing in a tin dish, a coarsely pulverised sample of ore which is known to certain galena and copper pyrites, the percentage of each of these minerals, which can be easily separated and roughly weighed, can be ascertained it will be possible to calculate the proportions of lead and copper within certain limits, and if either silver or gold, or both of these metals, be present in the ore, these can be estimated in the concentrated galena and pyrites.

Assays are not only purely chemical or metallurgical, for in certain cases they can be made mechanically, as in the washing process for gold or tin; and when ores are employed for certain purposes in the arts, their properties for these purposes can be tested on a small scale without any chemical analysis at all, and quite enough information can be gained to show whether the ore is worthy of any further chemical treatment.

The Blowpipe and Lamp or Candle.—The common mouth blowpipe sold by wholesale druggists, or the one used by jewellers, will answer all the purposes of the prospector; or a very useful and cheap blowpipe case, known as the Society of Arts' blowpipe case, can be obtained. The cheap blowpipe intended for mineralogical tests is made conical, and sufficiently large from the mouth end to the extremity (which connects with the

small tube directed towards the flame), for the moisture to accumulate in the widest part, as otherwise it would spoil the test. It is necessary, of course, from time to time, to shake the blowpipe and expel the water.

A common candle will be found sufficient in most cases, but for reductions of metals, when a hotter and more powerful flame is required, a mixture of methylated spirit or alcohol with turpentine or benzine will be necessary. According to the strength of the spirit, the proportions will be from 6 to 12 parts of spirit to 1 part of turpentine, or about 4 parts of spirit to 1 of benzine. This mixture can be burnt in the common glass spirit lamp used by chemists, but with a flat wick fitting in a suitable socket, and of about half an inch in width by one-fifth of an inch in thickness.

The Use of the Blowpipe requires great practice, and it is

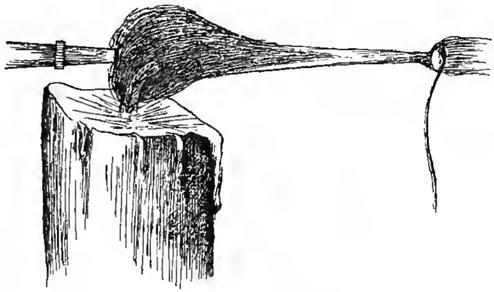


Fig. 3.—Oxidising and Fusing Flame.

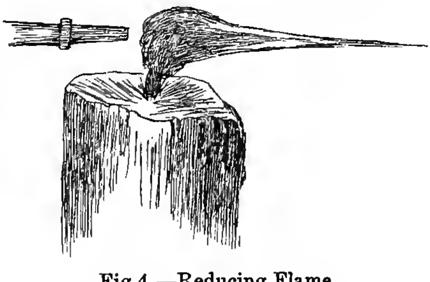


Fig 4.—Reducing Flame.

probably not so difficult to acquire as it is to explain. The blast is not obtained by sending air direct from the lungs, but

by accumulating it in the mouth, the cheeks being inflated, and then sending the air into the blowpipe by the action of the muscles of the cheeks. The operations which have to be conducted with the blowpipe consist of fusions, oxidations, and reductions. Fusion will require the use of the hottest part of the flame; oxidation, a sufficient access of air into that part of the flame in which the assay is placed; and reduction will require air to be excluded from the assay, in which case the combustible materials in the flame which require oxygen to burn them will extract that oxygen from the mineral being tested.

The foregoing drawings illustrate the different results, either oxidising or reducing, which can be obtained by the use of the blowpipe.

The Oxidising and Fusing Flame.—The wick should be cut a-fresh, parallel to the inclined rim or socket, if the lamp is used, since a charred wick will produce bright yellow bands in the blue cone of the flame, which are rich in carbon and possess a reducing action. The nozzle of the blowpipe must be placed a little in the flame, and nearly touching the wick, so as to send the air into the middle of the flame. The blast should be moderately strong, and the inner part of the flame produced will be a long pointed bluish cone, which is a little brighter near the point; the outer part will be very thin and pointed, of a light blue colour, and scarcely visible. The bright point of the inner cone is the hottest part, and in it the minerals to be fused will be placed, whilst those to be oxidised will be held a little beyond this point in the outer flame where the oxygen is plentiful.

The Reducing Flame.—The flame of the lamp or candle should be stronger than in the first instance; and, if possible, the blowpipe should be used with a smaller aperture, or the blast should be moderate, so as to obtain but an imperfect combustion. At the same time, the point of the blowpipe must not penetrate into the flame, and the air should pass a little above the wick. The flame will then take the shape of a long, bright cone, surrounded by a pale blue flame slightly visible, the obscure inner part being shorter than in the oxidising flame.

Reagents.—The only reagents which will be absolutely necessary are borax, carbonate of soda (calcined), and, rarely, microcosmic salt, nitrate of cobalt, and a little hydrochloric and sulphuric acid. A few others are occasionally necessary, but their use is limited.

Accessories.—Some platinum wire, platinum forceps, a small pestle and mortar made of agate, a small sieve, a magnet, some

small glass tubes, and some good firm charcoal, practically complete the necessary equipment.

Fusibility.—The ease or difficulty with which minerals are fused, while not affecting their chemical composition, is frequently of use in their discrimination. Nearly all the sulphides are fusible—*e.g.*, *stibnite* and *pyrites;* and some silicates containing soda or potash are also very easily fusible—*e.g.*, *zeolites;* many oxides are infusible—*e.g.*, *chromite* and *corundum*—as also are many silicates, carbonates, sulphates, &c., containing oxides of alumina, magnesia, lime, &c., in considerable quantities. Zinc forms many infusible compounds, and sulphide of zinc or *zinc-blende* is the only infusible sulphide.

As a rule, minerals composed of several oxides are more easily fusible than those in which only one of the infusible oxides is present. The following is the scale of fusibility generally adopted for purposes of comparison:—

1. *Stibnite.*—Fuses easily in the candle flame.
2. *Natrolite.*—Fuses in the candle flame.
3. *Almandine garnet.*—Fuses easily even in large fragments before the blowpipe.
4. *Hornblende,* var. *Actinolite.*
5. *Orthoclase,* var. *Adularia.*

$\left.\right\}$ Fuse more or less easily before the blowpipe in minute fragments.

6. *Bronzite.*—Small fragments are only rounded on the edges before the blowpipe.
7. *Quartz.*—Infusible in the ordinary blowpipe flame.

Colour of Blowpipe Flame.—Certain minerals, when heated before the blowpipe, impart characteristic colours to the flame. The mineral should be used in small scales or fine powder. In the first case it should be held by the platinum forceps, and in the second taken up on red-hot platinum wire. In both cases the platinum must be quite clean, and impart no colour itself to the reducing flame. Platinum is best cleaned by heating it red hot, and plunging it into sulphuric acid.

Flame colour-tests can be made either by strongly heating the mineral in the reducing flame, moistening with hydrochloric acid, and heating again; or, which is better, if the wick of the candle be trimmed very short, and the mineral be heated and then brought rapidly in contact with the wick, the flame coloration is observable as a flash which is very distinctive

The flame colorations are as follow :—

Red Flame.—*Strontia, Lime,* or *Lithia.*—Of these, the lime flame is yellowish-red, and that of strontia and lithia purple-red. The strontia coloration does not disappear when looked at through blue glass (coloured with cobalt), while that produced by lime and lithia is extinguished.

Yellow Flame.—All compounds containing soda.

Green Flame.—Minerals containing baryta—*e.g., barytes* and *witherite*—give a yellowish-green flame.

Minerals containing copper (except in the presence of chlorine or bromine) colour the flame emerald-green.

Phosphates—*e.g., apatite* and *pyromorphite*—when moistened with sulphuric acid and held so as scarcely to touch the borders of the flame, impart to it a very pale bluish-green colour. Borates moistened with sulphuric acid and held in the flame of the spirit lamp, without blowing, colour it green approaching emerald in tint.

Blue Flame.—Chloride of copper gives a blue flame with a purple border, and bromide of copper greenish-blue. All copper minerals moistened with hydrochloric acid yield this reaction.

Violet Flame.—Some minerals containing potash colour the flame violet, but the smallest trace of soda is sufficient to destroy this colour. If a strip of blue glass is used a beautiful purple colour is seen through it.

COLOUR OF BORAX BEADS.—A loop having been made in the platinum wire, sufficient borax should be taken up and fused in the loop to form a clear transparent bead. A small quantity of the mineral to be tested being fused with this, the bead will be coloured if certain substances are present. It should be understood that in applying colour tests either with borax beads or flames the minerals must be pure, because when complex compounds are treated the different colours are liable to obscure one another. Consequently, colour tests are only characteristic for minerals which are not too complex in composition. The following are the characteristic colours of borax beads:—

Cobalt.—Bead of a deep blue colour in both oxidising and reducing flame.

Copper.—Bead blue in oxidising flame, and red and opaque in the reducing flame.

Titanates and Tungstates.—Bead colourless in the oxidising flame, and violet-blue in the reducing flame.

Manganese.—Bead violet in the oxidising flame, and colourless in the reducing flame.

Nickel.—In the oxidising flame the bead is violet when hot,

and pale reddish-brown when cold. In the reducing flame the bead becomes grey from the reduction of nickel oxide to the metallic state.

Chromium.—The bead is always green.

Uranium.—Bead yellow in oxidising flame, and green in reducing flame.

Iron.—In the oxidising flame the bead is yellow to red while hot, and from colourless to yellow when cold. In the reducing flame the bead is bottle green.

Colours of Microcosmic Salt Beads.—This salt is not so often used as borax; it requires the loop of the platinum wire, and consequently the bead, to be much smaller, as otherwise, the fused salt being more liquid, it would not adhere to the wire. With few exceptions, the colours imparted by metallic oxides are the same as those already mentioned for borax, but they are often more vivid.

With microcosmic salt iron gives, in the reducing flame, a reddish bead; whilst with borax, in the same circumstances, it it bottle green. Uranium, instead of a yellow bead in the oxidising flame, gives a green one.

Tests on Charcoal.—One of the most useful and practical tests for minerals is that which can be made with a piece of charcoal, or even a small wooden stick put in a solution of carbonate of soda and burnt at one end. A small hole is made at one extremity of the charcoal, and a piece of the mineral, about the size of a mustard seed, put into it. Some minerals possessing an easy cleavage decrepitate or fly when heated before the blowpipe, and they will have to be used in powder.

The fusibility of the mineral will, of course, be observed, but the principal characters that can be detected depend chiefly upon the easy reduction, oxidation, or volatility of certain substances. A few give off a characteristic smell on volatilisation. Minerals which contain sulphur, as sulphides, yield fumes with the smell of burning sulphur; arsenic gives a smell of garlic; and selenium one of horse radish.

Some metals of easy reduction, but which unite quickly with oxygen at a high temperature, yield only a pulverulent coating of oxide. Zinc gives a yellow coating when hot, which becomes white when cold. Cadmium gives a brownish-yellow coating. Other metals give, at the same time, a metallic bead and a coating of oxide. A bead of lead will be known by its malleability and a yellow coating on charcoal. Bismuth is brittle, and the coating is yellow; antimony is also brittle, but the coating is white.

Metals can be reduced without giving any coating when they are not easily oxidisable, such as gold, silver, or copper. It is very easy to observe the malleability of a bead thus formed by striking it with a small hammer on a clean surface of an anvil.

Some iron minerals, especially oxides, and some compounds of nickel and cobalt give, when treated on charcoal, a partly reduced grain which is attracted by the magnet.

Tests on Charcoal with Carbonate of Soda.—Certain metals of less easy reduction will be obtained in the metallic state by mixing them with carbonate of soda in fine powder and treating them on charcoal with the blowpipe; the minerals mentioned under the foregoing division will exhibit the same characters, and will be more easily reduced than with charcoal alone.

Tinstone, which is an oxide of tin, mineralogically called cassiterite, is very difficult to reduce on charcoal with carbonate alone; but with cyanide of potassium it is easily reduced in small globules, which can be flattened out in the agate mortar in water, and are easily recognised.

Sulphates—*e.g.*, *gypsum, barytes, alunite, anglesite*, &c.—when fused with carbonate of soda on charcoal are reduced with the formation of sulphide of soda (a mass of liver colour called hepar). If the fused mass be placed on a clean silver coin with a drop of water it will leave a black stain of sulphide of silver.

Tests with Carbonate of Soda and Nitre.—Manganese and chromium may be detected when heated on a piece of earthenware or platinum, after having been mixed with the above reagents, by forming, the first a green, and the second a yellow mass. Nitre is necessary in these tests as, containing a large quantity of oxygen, it supplies it for the formation of the compounds, which are both salts containing a large proportion of oxygen—viz., manganate and chromate of soda.

Tests with Nitrate of Cobalt.—Nitrate of cobalt dissolved in water, and used in exceedingly small quantity, helps to discriminate between certain white minerals—*e.g.*, *kaolin, meerschaum, magnesite, dolomite*, &c. The mineral is reduced to powder and moistened with a drop of a very light solution, and then heated before the oxidising flame of the blowpipe. Kaolin and other minerals containing alumina assume a rich blue colour, while meerschaum and other minerals containing magnesia become flesh coloured. Oxide of zinc, under the same circumstances, becomes green, and this can be tried with the white coating obtained on charcoal by reducing an ore of zinc with carbonate of soda.

Tests in Glass Tubes.—These can be better made over a spirit lamp, so as to avoid the deposit of soot on the glass; but they can also be made with the blowpipe flame, provided it is used carefully, avoiding too sudden a heat, which would break or fuse the glass. The presence of water in minerals will be detected in this way, and the water collects in small drops in the cold part of the tube. Hydrous minerals which are likely to give this result will be easily found in the list of minerals.

Some minerals containing sulphur, arsenic, antimony, tellurium, and selenium often give a characteristic deposit.

Minerals containing mercury can also be tested in this way, as by adding a little carbonate of soda, sometimes with cyanide of potassium, a sublimate of metallic mercury will be formed in the cold part of the tube. A little charcoal should be added to arsenical minerals.

Organic combustible minerals generally leave a deposit of carbonaceous matter at the bottom of the tube, and the volatile hydrocarbons condense in the cooler part; the tube should therefore always be long enough to allow for this condensation. Minerals which yield a characteristic smell will be best tested in this way.

Determination of Minerals.

The present scheme will be found to answer in most cases for the identification of minerals of common occurrence, but will not discriminate between the many rarer species. Fully a thousand minerals have been described from time to time, but in this book it is not proposed to deal with more than about one hundred which are of common occurrence. In any case, however, the system adopted will give some clue as to the nature of an ore.

The physical characters already described may, in some cases, render it unnecessary to follow out the course of the tables given below, but, when any doubt exists, the systematic tests enumerated are best followed.

Minerals have been divided for purposes of identification into

(*a*) Minerals with metallic lustre.
(*b*) Minerals without metallic lustre.

Some doubtful minerals exhibiting a semi-metallic lustre—*e.g.*, *zincblende*—are placed in both groups.

An attempt has been made to form groups of the useful minerals, so that each group could be easily recognised by one or

more characters. All the ores of copper, for instance, yield a bead of copper when treated on charcoal with soda before the blowpipe, so that the group of copper minerals can be separated at once and the different minerals identified in the manner described in the chapter on Copper Ores.

Many minerals are mentioned in the tables which have no apparent value to the prospector, but had a scheme of determination been drawn up for only the most common minerals, say fifty in number, mistakes would have been unavoidable when any rarer minerals, not so included, were found. In the present scheme all minerals of any importance to the prospector are included as well as many which, while of no economic importance, are likely to be met with, and no time will be lost in discrimination if the directions are intelligently followed. As regards the metallic ores, they can be classed as silver, copper, lead, &c., without pushing the inquiry any further if it is only desired to form an estimate of the nature of the ore and not to determine the mineral species.

Although, as already stated, some of the minerals included in the tables would not, at first sight, appear to be of any importance to the prospector, they are, many of them, of indirect importance as constituents of certain rocks. It will be seen how intimately connected with the different mineral deposits are the characters of the rocks in which they occur, and a prospector who would acquire the scientific knowledge which underlies his business must learn to distinguish the different classes of rocks, the first step towards which is the recognition of the minerals composing them. It is perfectly true that in prospecting for valuable ores a thorough knowledge of the eruptive and other rocks is of scarcely less importance than the discrimination of the ores themselves.

Minerals with Metallic Lustre.

The native metals which are malleable may be recognised at once; they are *platinum*, *gold*, *silver*, and *copper*. *Mercury* and and the *native amalgams* can also be easily recognised. *Silver glance* alone, which is so malleable and sectile as to be mistaken for lead, would have to be further tested for sulphur with the blowpipe to be identified with certainty; but native lead is extremely rare, and silver glance is not likely to be confounded with silver. Platinum will be recognised by its infusibility before the blowpipe.

Minerals Easily Fusible or Volatile.

I. *Before the blowpipe, give smell of garlic due to arsenic.*

(*a*) With soda on charcoal give, before the blowpipe, a bead of copper (see Copper Ores and Silver Ores for *polybasite*).

(*b*) With borax give, before the blowpipe, a blue bead due to cobalt (see Cobalt Ores).

N.B.—Some nickel ores occasionally contain enough cobalt to give this reaction, but otherwise they give a brown bead.

(*c*) Before blowpipe, do not give the above results, but in a glass tube afford a crystalline sublimate of arsenic.

If the mineral, after having been heated for a long time before the blowpipe on charcoal, melts to a black magnetic bead it is *mispickel;* but if, in the tube, it is completely volatile it is *native arsenic.*

II. *Before the blowpipe, give off abundant white fumes without smell, due to antimony.*

N.B.—A smell of sulphur or arsenic may sometimes be observed in minerals belonging to this group if these substances are present in sufficient quantities, but the white fumes of antimony are characteristic. At the commencement of the operation the charcoal is covered with a heavy white coating which does not colour the flame; but this must not be confounded with the ashes of the charcoal which sre also white, but are very light.

(*a*) With soda on charcoal give a bead of silver (see Silver Ores).

(*b*) On charcoal with soda give a bead of copper after the lead present has been oxidised; leaves also a dark red coating on the charcoal (see Copper Ores; *bournonite*).

(*c*) On charcoal, before the blowpipe are almost, or entirely, volatile.

Native antimony is entirely volatile, leaving a white coating; there is no smell of sulphur, and the metal is tin-white.

Stibnite (see Antimony Ores) is lead-grey to steel-grey, and is also entirely volatile, but forms a black slag at first, and a smell of sulphur can also be detected.

Jamesonite and Zinckenite (see Lead Ores) are lead minerals containing antimony, are not of common occurrence, and are not entirely volatile. With soda they afford a bead of lead as also a smell of burning sulphur, and, in the oxidising flame, a yellow coating on charcoal.

N.B.—Some galenas when mixed with stibnite give the same reactions; but galena will be recognised by its three cubic cleavages, while zinckenite is not cleavable, and jamesonite has only one cleavage.

III. *Before the blowpipe, give a smell of sulphur without white fumes, and treated with soda on charcoal form an alkaline sulphide.*

N.B.—The bulk of carbonate of soda used should be three times that of the assay; when the mass is melted it is separated from the charcoal with the point of a knife and placed on a silver coin with a drop of water. If sulphur is present a brown stain will be formed on the silver.

(*a*) On charcoal with soda, before the blowpipe, give a bead of copper (see Copper Ores and Silver Ores for *Stromeyerine*).

Stromeyerine will be identified by dissolving in nitric acid and precipitating with salt, a white flocculent precipitate of chloride of silver being formed.

(*b*) On charcoal with soda, before the blowpipe, give a bead of silver (see Silver Ores).

Silver glance is easily sectile and very fusible.

(*c*) On charcoal with soda, before the blowpipe, give a malleable bead of lead and, in oxidising flame, a yellow coating in the charcoal (see Lead Ores—*Galena*).

(*d*) Treated as above give a brittle bead of metallic bismuth (see Bismuth Ores).

(*e*) Treated as above yield a magnetic mass.

Millerite (see Nickel Ores) is a rare mineral of a brass-yellow colour and occurs in capillary crystals.

Pyrites (see Iron Ores) occurs as brilliant crystals or massive of a light brass-yellow colour, and is hard enough to scratch glass.

Sternbergite (see Silver Ores) is of a bronze-yellow colour, does not scratch glass, and yields a magnetic bead containing silver.

Nicopyrite (see Nickel Ores) is bronze-yellow or copper-red, does not scratch glass, and with microcosmic salt forms a bead which is red when hot, yellow when cold.

Pyrrhotine (see Iron Ores) is bronze-yellow or copper-red, does not scratch glass, and with microcosmic salt gives a green bead in the reducing flame, while in the oxidising flame the colours are the same as for nicopyrite.

IV. *On charcoal, before the blowpipe, a smell of horse-radish is evolved due to selenium.*

Selenium occurs combined with lead, copper, mercury, and silver forming minerals which are very rare, and are not again mentioned in this book.

V. *On charcoal, before the blowpipe, give a white coating which becomes green or greenish-blue before the reducing flame.*

When heated in a glass tube with excess of concentrated sulphuric acid the solution assumes a purple or hyacinth colour, which disappears when water is added, a greyish-black dust falling to the bottom of the tube. This dust is tellurium, a rare metal which occurs in many minerals, especially with silver, gold, and lead (see Tellurium Ores).

VI. *A few minerals which melt more or less easily do not answer to any of the foregoing characters and will be considered here.*

(*a*) Reddish silver-white, brittle; specific gravity 9·7 (heavier than copper), very brittle and easily fusible; **native bismuth.**

(*b*) Red, dust cherry-red, brittle. On charcoal with soda yield a bead of copper. **Cuprite** (see Copper Ores).

(*c*) Black, not easily fusible or nearly infusible.

Wolfram (see Tungsten) is black, dust dark brown-red or brown-black with a semi-metallic lustre; its specific gravity is 7 to 7·5; and it is fusible to a magnetic globule with crystalline surface.

Hæmatite (see Iron Ores) is black to red in colour and the dust red. It is practically infusible, but before the reducing flame becomes magnetic.

Magnetite (see Iron Ores) is black, and the dust is black; it is magnetic, and fusible with difficulty.

Psilomelane (see Manganese Ores) is black, and the dust is black; with borax it gives a violet bead due to manganese; or a green mass with nitre and carbonate of soda.

Minerals Infusible or Fusible with more difficulty than Orthoclase—not Volatile.

I. *On charcoal, in reducing flame, become magnetic, or are magnetic in their natural state* (see Iron Ores).

N.B.—Titanic iron and some chromites would be included here; and zincblende sometimes contains enough iron to become magnetic under the above circumstances, but if treated with hydrochloric acid zincblende evolves a smell of rotten eggs due to sulphuretted hydrogen.

II. *With borax a small quantity of the mineral gives a violet bead; does not become magnetic as above* (see Manganese Ores).

III. *Minerals which do not answer to the above characters.*

(*a*) Minerals pitch black, hardness over 5.

Chromite (see Chromium Ores); powder, yellowish-brown.

Pitchblende (see Uranium Ores); powder, greenish-black.

(*b*) Minerals, lead-grey or iron-black, very soft, will mark on paper like a pencil.

Molybdenite (see Molybdennm) is lead-grey in scaly and flexible laminæ.

Graphite (see Carbon); iron black, not generally scaly.

Minerals without Metallic Lustre.

Minerals Soluble in Water.

I. *Found in Metallic Mines.*

(*a*) Colour blue; with soda on charcoal, before the blowpipe, yield a bead of copper; **sulphate of copper** (see Copper Ores).

(*b*) Colour green; with soda on charcoal, before the blowpipe, yield a magnetic mass; **sulphate of iron** (see Iron Ores).

(*c*) Generally colourless; found chiefly in old metallic mines; before blowpipe, on charcoal fuse, and give white incrustation, which turns green with nitrate of cobalt; **goslarite** (see Zinc Ores).

The most common of the above metallic sulphates, and most likely to attract attention, is the sulphate of copper, but sulphate of iron is also common in some mines, and goslarite is not infrequently met with.

II. *Not generally found in metallic mines.*

These are generally colourless, or are coloured in light shades; *e.g.*, **alum**, **rock salt**, &c. (see Soluble Salts).

Minerals Insoluble in Water.

I. *Burn or volatilise before the blowpipe.*

N.B.—No mineral harder than quartz will occur in this group.

(*a*) Smell of sulphur in burning.

Native sulphur, characteristic yellow colour, and very brittle.

Cinnabar (see Mercury Ores) of a deep red colour, entirely volatile. With soda gives drops of mercury.

(*b*) Smell of garlic in burning; due to arsenic.

Orpiment (see Arsenic Ores) of a yellow colour, with a resinous, greasy, or nacreous lustre.

Realgar (see Arsenic Ores) of a red or orange colour, with a resinous or greasy lustre.

(*c*) Volatilise, giving off dense white fumes.

Oxides of antimony (see Antimony Ores).

(*d*) Burn or volatilise without exhibiting the above peculiarities.

See Carbon Minerals.

II. *Before the blowpipe melt more or less easily.*

The least fusible mineral of this group is orthoclase, which fuses only when in small scales or fragments. All those minerals which in very thin scales can only be rounded on the edges will be considered as infusible, or nearly so.

(*a*) On charcoal with soda, before the blowpipe, yield a metallic bead or powder, non-magnetic.

Kerargyrite, &c. (see Silver Ores), yield a bead of silver.

Atacamite, Malachite, &c. (see Copper Ores), yield a bead of copper, and colour the flame either blue or green.

Cerussite, &c. (see Lead Ores), yield a bead of lead.

Bismuth Ochre (see Bismuth Ores) yields a bead, which is brittle, but not magnetic.

Molybdite (see Molybdenum Ores) is not reduced to a bead, but can be obtained as a powder by crushing the fused mass and washing. The mineral is earthy and yellow in colour, and the coating becomes blue in the reducing flame, but the colour is transient.

(*b*) On charcoal with soda yield a magnetic mass, but it is sometimes necessary to reduce a considerable quantity before the magnetic properties can be observed.

Cobalt Bloom (see Cobalt Ores) and **several arseniates of iron and nickel** (see Iron and Nickel Ores) afford a smell of garlic on charcoal before the blowpipe, of which cobalt bloom may be distinguished by the blue coloration it imparts to the borax bead.

There are several other minerals which do not afford a smell of garlic, as follows :—

Wolfram (see Tungsten) ; as heavy as tin ore.

Vivianite (see Iron Ores) ; scratched by the nail and blue in colour.

Siderite (see Iron Ores) ; scratched by a knife, buff in colour, and powder effervesces with hot acid.

Lepidolite (see Micas) ; scratched by a knife ; colour, white, violet, or pinkish ; scaly before blowpipe ; colours the flame crimson.

Earthy Hæmatite (see Iron Ores) ; scratched by a knife ; gives a characteristic red streak and powder.

Rhodonite (see Manganese Ores) ; not scratched by a knife ; generally flesh red, powder rosy white ; with borax gives a violet bead due to manganese, and a green mass with nitre and carbonate of soda.

Garnets (see Gem Stones) are generally crystallised, and are harder than quartz.

N.B.—There are some other silicates which occasionally give a magnetic glass when fused before the blowpipe—*e.g.*, **hornblende, augite,** and some other ferruginous minerals, such as black tourmaline and epidote. Among the foregoing minerals **lepidolite** and **rhodonite** will only yield a magnetic mass in rare cases when they contain much iron, so they will also appear in another group.

(*c*) Minerals which yield a coloured powder and on charcoal with soda do not yield a metallic bead or magnetic mass.

Ultramarine or Lapis Lazuli (see Gem Stones) is blue, with a bluish-white powder, and can be scratched by a knife.

N.B.—A closely allied blue mineral, **hauyne,** answers to this description, but is only found in volcanic rocks, and is transparent, while lapis lazuli is opaque.

Rhodonite (see Manganese Ores) is not scratched by a knife, is generally flesh-red, and the powder rosy-white, while it exhibits the manganese reactions with borax, &c.

Garnet (see Gem Stones); generally red-brown or black in colour ; is not scratched by the knife ; generally crystallised ; and specific gravity about 4.

Cassiterite (see Tin Ores) ; red, brown, orange-yellow in colour, or black with a light grey or brown powder ; easily reduced with cyanide of potassium on charcoal to metallic tin.

Epidote (see Gem Stones) occurs crystallised in prisms of a dark pistache green ; colour of powder, grey.

(*d*) Minerals which yield a white powder and on charcoal with soda do not yield a metallic bead or magnetic mass.

Boracite (see Gem Stones) occurs crystallised in cubes, &c., and is about as hard as quartz.

Tourmaline (see Gem Stones) occurs in prisms. This division includes a great number of minerals which are scratched by quartz, some of which are compounds of lime, baryta, strontia, &c., such as anhydrite, selenite or gypsum, barytes, strontianite, witherite, cryolite, fluor spar, and apatite, none of which, with the exception of fluor spar and apatite, are harder than barytes. It also includes a still greater number of silicates, which all, with few exceptions—*e.g.*, **lepidolite** and **magnesite**—are harder than barytes, and most of them harder than fluor spar. These two divisions will be considered separately, under **insoluble salts** and **silicates,** and they may mostly be recognised by their physical characters and the colours they impart to the blowpipe flame.

III. *Before the blowpipe, infusible; or fusible with more difficulty than orthoclase, being only rounded on the edges when used in very thin scales.*

(*a*) As hard as quartz or harder than quartz.

N.B.—All the gems proper are to be included here, except **opal,** which is scratched by quartz; and tourmaline, which, in some varieties, is fusible. Tin ore is sometimes as hard as quartz, and being fusible, with great difficulty might be found here. It will be reduced on charcoal with cyanide of potassium.

Andalusite (see Gem Stones) is usually found in stout square prisms ; with nitrate of cobalt on charcoal the powder assumes a blue colour.

Disthene or Cyanite (see Gem stones) also assumes a blue colour with nitrate of cobalt, and usually occurs in flattened prisms which are white or blue in colour.

Quartz and the other gems do not assume a blue colour with nitrate of cobalt.

(*b*) Scratched by quartz; powder or streak coloured.

Siderite (see Iron Ores); powder light brown; effervesces with hydrochloric acid when warmed.

Diallogite (see Manganese Ores); powder reddish-white; borax bead violet.

Limonite or Brown Hæmatite (see Iron Ores); powder yellowish-brown; usually kidney shaped, concretionary or stalactitic; on charcoal with soda forms a magnetic mass.

Bog Iron Ore (see Iron Ores) ; powder ochre-yellow ; mineral earthy. On charcoal with soda forms a magnetic mass.

Chromite (see Chromium); powder brown; mineral, black with a lustre approaching metallic; borax beads green. On charcoal with soda forms a magnetic mass.

Pitchblende (see Uranium Ores); powder olive to brown; colours bead of microcosmic salt green when cold. On charcoal with soda does not form a magnetic mass.

Cassiterite (see Tin Ores); powder light grey or brown; elds metallic tin with cyanide of potassium on charcoal.

Chlorite (see Silicates of Magnesia); colour of powder greenish; mineral, green in small scales.

N.B.—Highly coloured serpentine will give a very light streak or powder, much lighter than the deep green or brown of the rock, and it will appear practically white compared with the colour of the rock itself. Some serpentines and the nickel ores of New Caledonia (silicate of nickel and magnesia) will be doubtful in this case, and therefore have also been included in the next group of the table. The nickel ore is apple-green; its powder is considerably lighter, but becomes green again when moistened. Among the differently coloured serpentines, those altered by exposure, and exhibiting a rusty colour will give a very light, but still yellowish, streak.

(*c*) Scratched by quartz; powder or streak white or very pale green.

Minerals containing alumina in considerable quantity in powder assume a blue colour with nitrate of cobalt on charcoal.

Zinc Minerals under the same conditions assume a green colour.

Some Magnesia Minerals under the same conditions assume a rosy hue.

Strontianite (see Insoluble Salts) effervesces with acid and colours the blowpipe flame crimson.

Calcite (see Insoluble Salts) effervesces with acid and colours the blowpipe flame yellowish-red.

Barytocalcite (see Insoluble Salts) effervesces with acid and colours the blowpipe flame first red and then yellowish-green.

Dolomite (see Insoluble Salts) effervesces with acid only when heated, and has a characteristic pearly lustre.

Apatite, Mica, Cassiterite, Rutile, Serpentine, and **Silicate of Nickel** do not effervesce with acid and will be found under their respective groups.

In illustration of the use of these tables, a crystal of **cerussite** or carbonate of lead may be taken, and it will be found—

1. It is a mineral without metallic lustre.
2. It is insoluble in water.
3. It does not burn or volatilise.
4. Before the blowpipe it melts more or less easily.
5. On charcoal with soda it yields a metallic bead which is not magnetic.
6. The bead is lead, being malleable and giving a yellow coating on charcoal. The mineral, therefore, belongs to the lead ores, and a reference to the chapter devoted to lead will easily distinguish cerussite from other lead minerals, for it effervesces in powder with hydrochloric acid, especially if warmed.

CHAPTER III.

ROCK-FORMING MINERALS AND NON-METALLIC MINERALS OF COMMERCIAL VALUE.

It is difficult to separate these two different classes of minerals, as some which form extensive rock deposits are commercially valuable; besides which it is inadvisable for purposes of discrimination to treat them separately.

Soluble salts are not of common occurrence, although some, like rock salt, occur as beds of great commercial value in sedimentary formations; while others, as natron or carbonate of soda, occur as surface efflorescences in dry countries, such as Egypt, where they have no chance of being dissolved and carried away by rain. The varied uses of rock salt are well known; its principal application is in the soda industries, but the consumption for domestic purposes is also considerable.

The most important potash mineral, **carnallite** (which is a chloride of potash and magnesia), occurs in the upper beds of rock salt at Stassfurt in Germany, and is scarcely known elsewhere; while the most important mineral source of nitre is **nitratine**, or cubic nitre, a nitrate of soda found in Peru and Chili, the working of which has during late years formed a most important and remunerative industry. In the district of Tarapaca, at a height of 3300 feet above the sea, the ground has been for about 40 leagues covered with beds of this salt, which were at places several feet in thickness, and associated with gypsum, common salt, glauber salt, and the remains of recent shells.

Sulphate of magnesia or Epsom salt, which is much used in medicine, occurs as an efflorescence in mines, especially where pyrites has undergone decomposition in presence of magnesian rocks. It is also found in caves.

Another soluble salt of value is **borax**, which is found crystallised on the basins of dried-up lakes in Thibet and California; in the latter locality, in the Calico district, some important beds of borate of lime are being worked which are interstratified with shales.

The soluble metallic salts, such as the sulphates of iron, copper, and zinc, are easily known; they are found in mines where iron pyrites, copper pyrites, or zincblende have become oxidised, and frequently occur in solution in the waters of certain mines, rendering them quite unfit for domestic purposes. In Southern Spain, the river called Rio Tinto has been so named on account of the quantity of sulphate of copper held in solution by it.

It will be readily understood that waters circulating below the surface of the ground dissolve some of these salts, and when they reach the surface as springs frequently contain a greater or less quantity of them in solution. These mineral springs are classified according to the minerals they hold in solution.

Earthy Carbonates and Sulphates, with Apatite, Fluor Spar, and Cryolite.

In this group are included fifteen minerals, only a few of which are very common—viz., **calcite, gypsum,** and **magnesite,** which are of universal occurrence; while some of the others are abundant in certain localities. Cryolite is only known from Greenland, but being a valuable mineral it cannot be omitted.

Five non-metallic minerals may be considered as lode-forming minerals; the most important of these—viz., quartz—will be subsequently described. The four others are **calcite, barytes, witherite,** and **fluor spar;** while others—*e.g.*, **apatite**—occur less frequently in reefs.

Carbonate of lime crystallises in two distinct systems, and the name of **calcite** or **calc-spar** is reserved for those crystals which, while occurring in a great variety of forms, can all be reduced by cleavage to a rhombohedron. Calcite occurs in reefs, and sometimes, especially in limestone countries, accompanies auriferous quartz, and even carries gold itself, as at Gundagai and Tuena in New South Wales, and Gympie in Queensland. It also occurs crystallised in rents and fissures in limestone.

Although crystallised calcite occurs in metalliferous veins in many countries—*e.g.*, Derbyshire and Cumberland in England, and the Hartz in Germany—the largest crystals are found in Iceland, where it is very pure and transparent, and is called **Iceland spar.** It exhibits the property of double refraction most perfectly, and on that account is used in the construction of some optical instruments. Probably Iceland can boast the largest natural crystals in the world, since specimens of calcite are recorded from there in single rhombohedrons six yards in length.

The other species of carbonate of lime is called **aragonite**

EARTHY CARBONATES AND SULPHATES, WITH APATITE, FLUOR SPAR, AND CRYOLITE.

Minerals.		Composition.	Hardness.	Specific Gravity.	Remarks.
Dolomite,	Carbonates.	Ca Mg	3½-4	2 9	Crystals often curved and saddle shaped; lustre pearly (pearl spar).
Magnesite,	Carbonates.	Mg	3½	2·17	In serpentine, not common.
Hydromagnesite,	Carbonates.	Mg water	3½-4½	3	Lustre sometimes nacreous on cleavage faces.
Calcite,	Carbonates.	Ca	3	2·5–2·8	If burned gives lime.
Aragonite,	Carbonates.	Ca	3½-4	2·9	Prisms, often in groups.
Strontianite,	Carbonates.	Sr	3½-4	3·7	Lustre greasy on fracture.
Witherite,	Carbonates.	Ba	3-4	4·3	Lustre greasy on fracture; occurs in veins.
Barytocalcite,	Carbonates.	Ba Ca	4	3·6	Needle shaped; yellowish-white.
Anhydrite,	Sulphates.	Ca	3-3½	3	Generally found with gypsum and rock salt.
Gypsum,	Sulphates.	Ca water	1½-2	2·3	When burned swells up, becomes opaque and forms plaster of Paris.
Celestine,	Sulphates.	Sr	3-3½	4	Crystals white, often with a bluish tinge.
Barytes,	Sulphates.	Ba	2½-3½	4½	Very heavy; occurs in veins.
Fluor spar,	Fluorides.	Ca	4	3·1	Occurs in veins; phosphorescent when heated.
Cryolite,	Fluorides.	Al Na	2½	3	Fusible in candle flame.
Apatite,		Phosphate of Ca with fluoride or chloride of Ca.	5	3·2	Lustre greasy on cleavage faces and fracture; angles and edges often rounded.

Al, Aluminium; *Mg*, Magnesium; *Sr*, Strontium; *Ba*, Barium; *Ca*, Calcium; *Na*, Sodium.

because some of the most perfect crystals have been found in Aragon in Spain; it crystallises in prisms. Aragonite forms many of the stalactites in limestone caves, and it also occurs in radiated kidney-shaped masses in cavities in basalt. When recently deposited from lime springs and stratified in beds it forms what is known as **calcareous tufa or travertine,** but calcite also occurs in similar deposits.

Before the blowpipe aragonite whitens and falls to pieces, but in other respects resembles calcite. The reason for this behaviour before the blowpipe is explained by the fact that under the influence of heat aragonite is changed to calcite and splits up into a number of small rhombohedrons.

Limestone forms extensive sedimentary deposits in beds of all ages, and when subjected to metamorphic action takes a crystalline form, the pure varieties which are white and fine grained, and are suitable for statuary purposes, being called **saccharoid marble.** Marbles assume every colour and shade according to the substances which are mixed with them; in the Devonian and Carboniferous formations, where fossil corals are plentiful, marbles are found which exhibit, on polished sections, the star-like forms of the corals of which they are composed. When a marble consists of broken fragments which have been subsequently cemented by an infiltration of carbonate of lime it is called a **brecciated marble.**

Marbles which are pure white or of a characteristic colour will always be valuable, but for a deposit to be properly worked the means of transit must be easy. The stone must be free from quartz veins or fossils transformed into quartz, and be easily obtained in blocks or slabs of large size, suitable for ornamental work. Marble has to be sawn with toothless stone cutters, but softer limestones, which have not been metamorphosed, can easily be cut with a toothed saw; these softer limestones are called freestones, and are used for building purposes; they usually occur in the later formations, such as the Oolitic limestone of Bath, or the Oamaru stone of New Zealand.

Lithographic stone is a very compact and fine-grained limestone, free from veins and fossils, easily cut into large slabs, and of a light colour. A lithographic stone possessing these qualities is not obtained in many places, and will always command a good price.

Limestones are also of value for smelting purposes or for burning for quicklime, and, according as they contain certain proportions of other materials, may be of value for the manufacture of hydraulic lime or cement. It is not, however, possible

for the prospector to determine these properties in the field, and samples should always be submitted to a chemist, and, if sufficient inducement offers, to cement manufacturers.

The next most important mineral of this group is gypsum, which is extensively used for building purposes. It is a hydrous sulphate of lime, which loses its water and falls to powder when burnt; this powder, which is perfectly white when free from iron, possesses the property of re-absorbing the water lost, and in a very short time of assuming again the solid state, expanding slightly in so doing. It is this last property that renders plaster of Paris so valuable for obtaining casts.

Gypsum occurs in lenticular masses of considerable extent in the fresh-water Tertiary formation at and near Paris. The large arrow-head shaped crystals which are to be seen in all collections of minerals are exceptional in these deposits, the whole mass being in a compact sugar-like state. Gypsum also frequently exists in groups of crystals arranged around a centre, and is found in isolated crystals in salt lakes, such as occur in South and Western Australia, a small proportion of sulphate of lime being present in the water. It is also found crystallised in clay beds in New South Wales and elsewhere. The incrustations, which form in boilers on board steamers, are mostly composed of sulphate of lime. Gypsum is occasionally found in mines where decomposition of pyrites has taken place in the presence of calc spar or limestone.

Anhydrite, which differs from gypsum by the absence of water, occurs in rocks of various ages, especially in limestone and those which contain gypsum, and is also very common in beds of rock salt; gypsum is often found to proceed from the decomposition of anhydrite.

The fibrous structure and silky appearance of some minerals has already been explained, and reference made to the occurrence of calc spar and gypsum in this state, as well as to their value for ornamental purposes. The fine-grained forms of both these minerals are sometimes called alabaster, but the term is generally applied to gypsum. The two varieties can be readily distinguished, as gypsum can be scratched by the nail, while calcite cannot.

Dolomite is carbonate of lime and magnesia, and crystallises like calc spar. Dolomitic limestones contain variable proportions of magnesia and lime. Very many limestones are thus, partly or wholly, dolomitic, and some of them burn to very good hydraulic limes. The dolomitic limestone of Ohio, U.S.A., is of special interest as forming the reservoirs in which the petroleum

of that field is stored, it being argued by geologists that the dolomitisation has resulted in innumerable small cavities being left in the limestone, which is thus enabled to act like a sponge.

Magnesite is carbonate of magnesia. It is rarely crystallised, occurs in talcose schists, serpentine, and other magnesian rocks, and is used for the manufacture of Epsom salt. Pure white magnesite has been observed to arise from the spontaneous decomposition of the heaps of refuse from shafts on mines ; pebbles are quickly cemented together by it, and timber, old tools, &c., encrusted.

Hydromagnesite, which differs from magnesite by containing water, occurs in earthy masses under similar conditions to magnesite.

Barytes and **Witherite** are respectively sulphate and carbonate of baryta, and both occur in veins, sometimes with galena or copper ores, as in Spain. Barytes is sometimes found in veins alone, and is mentioned in association with gold at Mitchell's Creek, New South Wales. Both barytes and witherite are used in the preparation of baryta and its salts, but witherite is far the more valuable mineral. It is used in sugar refining, and also in the manufacture of plate glass.

Celestine and **Strontianite** are sulphate and carbonate of strontia, and are used in the preparation of the salts of strontia for red fireworks. Celestine is usually associated with limestone, gypsum, rock salt, clay, and sulphur, while strontianite is found with galena and barytes in veins. The strong crimson colour imparted to the flame by these two minerals will always easily identify them.

The three minerals yet remaining to be dealt with under this group are apatite, fluor spar, and cryolite, all of great value for different purposes.

Apatite is a phosphate of lime with calcium chloride or fluoride, and occurs under the following conditions :—

1. In metamorphic strata, where it is supposed to have originated from animal matter (*Dana*). It thus occurs in the Laurentian rocks of Canada in green crystals of large size, and is also found in Norway under similar conditions.

2. As an accessory mineral in metalliferous veins, especially those of tin, and beautifully crystallised and of various colours in many eruptive rocks.

3. In veins by itself, mostly in limestone, but sometimes in granites and schists ; *e.g.*, Spain and France. In these deposits apatite also occurs as concretions, sometimes showing a radiated structure, but of an earthy appearance externally.

4. In sedimentary formations where a considerable accumulation of fossils has provided the phosphate of lime. In these deposits it occurs in two principal forms. (*a*) Coprolites, which are excreta of large animals, especially Saurians; and (*b*) concretions formed at the expense of the same coprolites, together with shells, bones, &c. The richest of these deposits are from Lower Cretaceous to Lower Jurassic in age, but phosphatic deposits are found and worked in sedimentary deposits of all ages.

Phosphate of lime is very valuable as a manure, and the deposits included under Groups 1, 3, and 4 are worked for this purpose.

Fluor Spar is a lode-forming mineral, sometimes alone, but also associated with other minerals, especially tin ore and galena. In the lead mines of Derbyshire and Cumberland, which are in limestone, it is found in beautiful crystals of conspicuous colours, and, when obtained in blocks of sufficient size, is worked into vases and other ornaments. In Derbyshire the blue and purple varieties are known to the miners as "blue john."

The presence of fluor spar in metalliferous veins is a great advantage, as it is a valuable flux for smelting, and when found in veins by itself it is mined for the same purpose. In addition to its value as a flux it is also used for preparing hydrofluoric acid for etching glass.

Cryolite also contains fluorine, but combined with aluminium and sodium. It forms very fusible compounds, and is used as a flux; but its principal application is for the manufacture of aluminate of soda, and as a source of the metal aluminium. It is also used in America for the manufacture of a white glass which imitates porcelain.

The two hardest of these minerals are apatite and fluor spar, and the heaviest are those containing baryta and strontia. All minerals of this group will answer to one of the following tests:—

1. Effervesce with acids either hot or cold; **Carbonates.**

2. Yield a stain on silver when fused with carbonate of soda and moistened with water; **Sulphates.**

3. Etch glass when treated with sulphuric acid in a platinum or lead dish; **Fluorides.**

4. Colour blowpipe-flame dirty green when moistened with sulphuric acid, and with magnesium wire in a closed tube evolve the disagreeable smell of phosphuretted hydrogen; **Phosphates.**

A reference to the characteristics in the table will serve readily to distinguish one from the other by the blowpipe tests already given.

Quartz and Opal.

Quartz is the most common substance with which the prospector has to deal, and it is therefore necessary to explain its characters. It is, chemically, silica or silicic acid, a compound of silicon and oxygen; and it may be remarked that silicon does not exist in nature, except in combination with oxygen, forming quartz and silicates.

In the blast furnace silica is not fused, but is reduced in very small quantities to silicon; whilst fusible silicates or slags are also formed. It is only by combination with oxides, such as lime, alkalies, metallic oxides, &c., that silica forms fusible substances in the blast furnace or before the blowpipe, and these fusible substances are termed **Silicates**.

The highest temperature which can be produced artificially is obtained by the combustion of hydrogen in oxygen, and this oxyhydrogen flame is employed to fuse both platinum and quartz, which are only fusible under the same conditions. Gold or silver at such a temperature fuse immediately and volatilise, forming a dense vapour.

The Stanhope pocket microscope, which is only about an inch in length, is made with a drop of fused quartz with one face cut; fused quartz has a specific gravity of 2·2 only. The specific gravity of the quartz in reefs, as well as that which occurs in granite and some of the acidic volcanic rocks, such as rhyolite, ranges from 2·5 to 2·8, pure quartz giving 2·65. The only natural form of silica known which has as low a specific gravity as 2·2 is a mineral called **tridymite,** which occurs in some of the highly silicated volcanic rocks, such as rhyolite and trachyte, and crystallises in small hexagonal tables, often occurring in groups of three crystals. Its chemical composition is the same as quartz.

These observations are of interest, because they show that, notwithstanding the views still held by many practical men, the quartz which forms our reefs and occurs in granite and other eruptive rocks has never been in a state of fusion.

Quartz can be produced artificially in microscopic crystals by the aid of superheated water; while the geysers sufficiently illustrate the solubility of silica in hot water charged with carbonic acid and its deposition therefrom. Quartz is always crystalline, for even in quartz reefs, where the mineral is compact, it is confusedly crystalline; while flint and the chalcedonies are minutely crystalline when seen under the microscope, but probably contain some amorphous opaline matter. Agates, which

are the only varieties of quartz of any value, consist of layers which are alternately crystalline quartz and variegated chalcedony.

In **opal** water is generally present, although Dana calls it unessential, and in the siliceous deposits from geysers the silica is still combined with water and the specific gravity is lower, ranging between 1·9 and 2·3.

Common opals are of frequent occurrence in eruptive rocks and in veins at the contact of serpentine with other beds. Even in sedimentary formations where siliceous concretions of flint are common, hydrous silica is also found, and is then opaque and resembles flint in appearance. The opal which is of value for ornamental purposes, and is sometimes called noble opal, will be dealt with under the head of gems. A substance of some value for industrial purposes, called **infusorial earth** or **tripoli**, is also hydrous silica. It is composed of microscopic organisms called diatoms, and is used in the preparation of dynamite and also in making soluble glass.

Silicates of Magnesia and their Crystallographic Allies.

It is necessary to divide the **silicates** into groups according to their chemical composition. Those first dealt with are all silicates of magnesia, and all are hydrous. When sufficiently pure, meerschaum, talc, and steatite will give before the blowpipe, when moistened with a solution of nitrate of cobalt, a pink mass which is characteristic of magnesia.

The first three minerals in the table are sufficiently soft to be scratched by the nail; but serpentine is harder, approximating in hardness to calcite.

None of these minerals, when pure, effervesce with acid; but if they contain an admixture of carbonate of lime, which is sometimes the case with serpentine and meerschaum, effervescence can be observed.

As regards fusibility, they are very refractory, being only fused with difficulty in small fragments and on thin edges.

Meerschaum, when pure, is very light; and, when dry, will float on water. It will be recognised by its property, when dry, of adhering to the tongue, and by its smooth, compact texture. It is generally found in serpentine, in which rock it occurs in nodular masses; but is also found in limestones of tertiary age. It is a useful substance when found in quantity, and of a snowy-white colour, being used, as everyone knows, for the manufacture of pipes.

Talc, Steatite, and Soapstone are, mineralogically speaking,

SILICATES OF MAGNESIA AND THEIR CRYSTALLOGRAPHIC ALLIES.

Minerals.	Principal Components.	Hardness.	Specific Gravity.	Colour and Streak.	Remarks.
Meerschaum,	Silica, magnesia, water	2	2·6–3·4	White, streak slightly shining	Earthy. Gives pink colour with cobalt solution before blowpipe.
Talc, . .	Do.	1–1½	2·7	Green or greyish	Pearly or resinous; greasy; laminæ flexible, not elastic. When heated, loses colour and emits light, but does not fuse.
Steatite, .	Do.	1½	2·7	Grey, green, yellow, &c.	Pearly; soapy to touch; fine splinters fusible to white enamel.
Serpentine, .	Silica, magnesia, iron, water	3–4	2·6	Green, yellow-reddish	Resinous or waxy. Becomes brownish-red when heated and loses water. Fuses at edges.
Chlorite, .	Silica, magnesia, alumina, iron, water	1½	2·7	Olive-green	Thin scales, slightly flexible, not elastic; fuses at edges only. Yields water when heated in glass tube.
White mica, (Muscovite),	Silica, alumina, potash	2–3	3	Silvery white	Laminæ thin, elastic, nacreous. Infusible or fuses only on edges to a grey or yellow glass.
Black mica (Biotite), .	Silica, magnesia, alumina, iron, potash	2½	2·9	Brown or black streak, greenish grey	Laminæ thin—lustre nacreous on cleavage. Before blowpipe whitens and fuses on thin edges; gives iron bead with borax.
Lepidolite, .	Silica, alumina, manganese, iron, lithia, potash	2½–4	3	Pink or yellowish	Lustre pearly in small scales or massive. Before blowpipe colours flame crimson.

the same mineral, of varying degrees of purity and in different modes of aggregation

Talc is the pure crystallised mineral, occurring in transparent laminæ, which can be bent, but are not elastic like mica. The colour of talc is often a light green or pearly-white, its lustre is nacreous or greasy, and it is characteristically soft and soapy to the touch. Steatite or soapstone is a massive variety of talc, and, when sufficiently homogeneous and free from cracks, it can be sawn into blocks and used as firebricks. Crushed and purified by washing, it is formed into cakes of different colours, and is used by tailors for marking cloth. Talc and its varieties occur associated with serpentine, magnesian limestone, and especially with talc and chloritic schists.

Serpentine is found in extensive masses, sometimes forming high mountain ranges; it also occurs in veins and beds, and is consequently to be considered as a rock of some importance. Its occurrence and distribution are, moreover, of interest, on account of the valuable mineral deposits—*e.g.*, gold, platinum, copper, nickel, and chrome-iron—frequently associated with it, and it is also the principal repository of meerschaum and soap-stone.

Chlorites and Micas are remarkable as occurring generally in thin laminæ easily separated one from the other, and transparent. They are all softer than calc spar, and are not easily fusible. These characters alone would not be sufficient to distinguish them from talc, but the greasy feel of talc will serve to distinguish it easily enough in most cases; besides which, talc is generally light green, while the most common variety of chlorite, which occurs in small grains or scales, is of a deep green colour. The micas are not likely to be mistaken for talc; the most common varieties are either white or black, and their plates are elastic, while those of talc are not, and mica does not feel soft or greasy.

Chlorites are hydrous silicates of magnesia, alumina, and iron, and there are varieties in which the proportions of these bases are different. In some, magnesia predominates, such as the variety called **pennine**; while in the variety called **ripidolite**, or simply **chlorite**, alumina is in the larger proportion, and iron in greater quantity than magnesia. They all fuse with difficulty before the blowpipe to a grey or black slag, and when iron is present in sufficient quantity this slag is magnetic. **Pennine** occurs in serpentine, often associated with other minerals, and **ripidolite** is the most common variety in chlorite schists, talcose schists, and amphibolites, being often associated with garnet, magnetite, &c.

Rocks and minerals of a dark colour, usually green, are fre-

quently associated with metalliferous deposits, especially those of copper and more rarely gold; and chlorite is frequently met with in metalliferous districts, not only with the dark or basic rocks but also accompanying tin, which always occurs in light or acidic rocks, such as granite.

Micas, especially when found in large plates, are both flexible and elastic, and this property renders mica very valuable when it is white and can be obtained in large sheets. It is sometimes used instead of window-glass on board ship, for stoves, and for chimneys for lamps. **Biotite,** or black mica, contains more magnesia than alumina, and is sometimes called magnesian mica; it is often present in eruptive rocks, especially some granites. **Muscovite,** or white mica, on the contrary, contains more alumina than magnesia, and as it also contains potash in small but appreciable quantities it is sometimes called potash mica.

Muscovite is an important mineral to the tin miner, since it is always found in that class of granite in which tinstone occurs, and with quartz alone forms the rock called greisen, which is very generally associated with tin. The rock in which large sheets of mica are found is called by some geologists pegmatite, and has the same composition as granite itself, but the crystals are all of larger size.

Muscovite also forms an essential part of other light coloured acidic rocks, such as gneiss and mica schist, and is sometimes found in granular limestone and some volcanic rocks, such as trachyte and basalt, but only as an accessory mineral. When found in small scales in sedimentary rocks it has probably been derived from the disintegration of granite, and it occurs under these conditions in many sandstones.

Lepidolite, or lithia mica, is a variety of muscovite containing practically no magnesia, and characterised by the presence of lithia, an alkali which is of value on account of its medicinal properties. Lithia mica will be readily recognised before the blowpipe, as it imparts a beautiful crimson colour to the flame, especially if powdered and mixed with a little fluor spar. It generally occurs in scaly granular masses in granite and gneiss, and is sometimes associated with limestone and tourmaline. It is very abundant in Bohemia; but the most plentiful supply of lithia is derived from a mineral spring in Cornwall; and it is probable that the lithia in this water is derived from the tin granites of the country. Lithia mica is associated with tin granites in Bohemia, Saxony, and France.

There are several magnesian minerals which have received different names, but are really only varieties of serpentine;

ANHYDROUS SILICATES OF LIME AND ALUMINA WITH THEIR CRYSTALLOGRAPHIC ALLIES.

(Crystalline Rock-forming Minerals.)

	Mineral.	Principal Components.	Hardness.	Specific Gravity.	Colour and Streak.	Remarks.
Felspar.	Orthoclase,	Silica, alumina, potash	6	2·55	Colourless, white, pink, greenish	Fusible to bubbly glass, blowpipe reaction for potash.
	Albite, .	Silica, alumina, soda	6-6½	2·6	White or pale	Fusible to bubbly glass.
	Oligoclase, .	Silica, alumina, soda, lime	6	2·7	White, greyish, greenish	Fusible.
	Labradorite,	Silica, alumina, lime, soda	6	2·7	White, grey, yellow, with coloured plays of light	More easily fusible, easily attacked by acids.
	Anorthite, .	Silica, alumina, lime	6	2·7	Colourless, white	Do.
Hornblende.	Tremolite, .	Silica, magnesia, lime	5½	3·2	White or pale green	Fusible with ebullition to white glass.
	Actinolite, .	Silica, magnesia, lime, and little iron	5–5½	3·3	Green, streak greenish-white	Fusible to a greyish glass.
	Hornblende,	Silica, magnesia, lime, iron	5½	3·4	Black or deep green	Fusible to greyish or black glass.
Augite.	Diopside, .	Silica, lime, magnesia	5-6	3·3	Colourless, white-green	Fusible to white or greyish glass.
	Diallage, .	Silica, lime, magnesia	4	3·3	Grey, greenish, brownish	Fusible to a grey or green glass.
	Hedenbergite,	Silica, lime, manganese, zinc, iron	...	3·5	Black or deep green	Fusible to a black magnetic glass.
	Augite, .	Silica, lime, manganese, iron, &c.	6	3·4	Black, deep green, generally opaque	Fusible to a black often magnetic glass.
Enstatite.	Enstatite, .	Silica, magnesia	5½	3·1	Greyish-white or yellowish	Nearly infusible.
	Bronzite, .	Silica, magnesia and little iron	5-6	3·2	Brown, yellowish-brown	Nearly infusible.
	Hypersthene,	Silica, magnesia, iron	5-6	3·3	Greenish or brown-black, copper - red plays of light	Fusible to a black magnetic glass.
	Wollastonite, .	Silica, lime	5	2·9	White or pale colours	Fusible with difficulty.

they are generally coloured green by the presence of a little iron or sometimes nickel. They generally occur in serpentine formations, and the deep green varieties are often associated with the silicated nickel ores.

Anhydrous Silicates of Lime and Alumina with their Crystallographic Allies.

The minerals of this group are all of great importance in forming rocks, especially those of eruptive origin; but topaz, tourmaline, olivine, epidote, and garnet, which less frequently play an essential part in the constitution of rocks, are included with the gems.

All minerals included in this group are anhydrous silicates, and may be subdivided as follows :—

1. **Felspars,** including orthoclase, albite, oligoclase, labradorite, and anorthite, which are silicates of alumina and other oxides.

2. **Hornblendes,** including tremolite, actinolite, and hornblende, which are silicates of magnesia, lime, and other oxides.

3. **Augites,** including diopside, diallage, hedenbergite, and augite, which are of similar composition to the hornblendes, with different proportions, however, of the component substances.

4. **Enstatite, bronzite and hypersthene**; the first is a silicate of magnesia; the last two are silicates of magnesia and iron.

It may be well here to refer to the table showing the composition of the eruptive rocks (p. 9).

Orthoclase.—If a piece of granite be taken and a variety composed of large crystals chosen, it will be found that, besides the scales of black or white mica, grains of quartz will be easily recognised by their transparency, irregular shape, and hardness; whilst the rest of the rock will be found to consist of a white, greyish, or pink mineral, scarcely transparent, and breaking easily in two directions, on one of the faces of which the mineral exhibits a nacreous lustre. If the facets produced by the fracture are large enough it will be seen that the two are at right angles to one another. This mineral is **orthoclase**, the most common and most important of all the felspars. It is also called potash felspar, and it is this mineral principally which, by its decomposition, forms deposits of kaolin or clay, the potash being dissolved. In some lavas it is stated to form an amorphous paste, whilst some well-formed crystals of orthoclase can also be detected; and it is also one of the component minerals of gneiss and many crystalline schists. These are all rocks, in the formation of which water, at a considerable temperature and under pressure, has taken a prominent part.

If, on the other hand, a specimen of trachyte be taken in which large crystals are developed, it will be found that crystals occur, which like orthoclase in granite, have two cleavages at right angles to one another, but a casual examination of these crystals will further show that they are transparent and vitreous. This constitutes another variety of orthoclase, known as **sanidine.** It characterises rocks, such as trachyte, in the formation of which heat has played an important part, which have, in fact, come to the surface in a state of fusion. Not only is the orthoclase in these rocks different in physical aspect from that of granite, but, as already pointed out, the quartz is sometimes replaced by tridymite, the specific gravity of which—viz., 2·2—is that of fused quartz.

Orthoclase, as well as the other felspars, is fusible before the blowpipe; so that a light-coloured granular or compact rock which is fusible in small fragments is most probably composed of felspar, and generally orthoclase. Some of the fusible rocks are granular or compact, but still of eruptive origin—*e.g.*, *eurite;* some are vitreous and compact—*e.g.*, *obsidian*—a black rock which is also called volcanic glass; and some are vitreous and porous—*e.g.*, *pumice*—in which the porous state has been produced by steam evolved in the interior of the molten mass. These are all of volcanic origin, but there are also rocks composed of very minute, even microscopic, grains of felspar which are truly sedimentary rocks, and are termed *euritines*. Orthoclase is used in the manufacture of porcelain and enamels.

Albite is a felspar, resembling orthoclase, in which soda replaces the potash. It is generally white, and occurs in some particular varieties of granite porphyry, diorite, gneiss, crystalline schists, &c. It is a rare mineral compared with orthoclase as a constituent of rocks, but some granites contain it as an accessory mineral; and it is also found forming veins in ordinary granite, being frequently the matrix in which the rarer associated minerals, such as beryl, tourmaline, &c., are imbedded.

Oligoclase is like albite, but contains a little lime. It generally occurs in laminar masses or crystals in the same rocks in which albite is found; its colour is generally white, greyish, greenish, or green. This mineral possesses an easier cleavage than the other felspars, and characteristic parallel striæ can be seen on the cleavage planes. The varieties of felspar which are used as ornamental stones, and are called sunstone and moonstone, are pure orthoclase or oligoclase with enclosed flecks of reflecting material.

Labradorite, like oligoclase, is rarely found in crystals, but

in cleavable laminar masses, the cleavage faces being striated. It is grey, white, yellow, &c., and on certain faces often exhibits a remarkable play of colours, such as blue, yellow, green, red, fiery, or semi-metallic. In this felspar lime is an important constituent, and there is also a small proportion of soda. It is more easily fusible than the other felspars, except oligoclase, and is in great part soluble in acids. It constitutes an important element in the basalts, but often occurs in such small crystals that it can scarcely be seen with the naked eye. An iridescent variety is found on the coast of Labrador in large masses, and forms a valuable ornamental stone.

Anorthite is a rarer species of felspar. It occurs in small white or colourless crystals resembling albite in shape, is almost entirely a lime felspar, and is easily fusible, although not so easily as labradorite; it is also attacked by hydrochloric acid. It occurs in granite, gabbro, serpentine, and many volcanic rocks.

The hornblende group includes three principal varieties in which the colour varies in proportion to the increasing percentage of iron present. **Tremolite,** containing little or no iron, is white; **actinolite,** containing a few units per cent. of iron, is green; and **hornblende,** containing much iron, is black. They are in consequence sometimes called white, green, and black hornblende. They are all fusible with ebullition before the blowpipe, the first forming a white, the second a grey, and the last a black bead.

The most common form in eruptive and metamorphic rocks is hornblende, the black variety, which occurs as a constituent of syenite, diorite, hornblende-andesite, hornblende-schist, &c., generally in the form of flattened prisms. It is also associated with augite in some modern volcanic rocks.

Actinolite occurs mostly in hornblende-schists, where it is frequently in the form of slender needle-shaped or flat prisms. These hornblende-bearing rocks, it may be remarked, are often connected with metalliferous deposits.

Tremolite is of much less importance as an element of rocks, but is interesting in other respects. It is more rarely found in well formed crystals than the two other varieties, but is often in baccillary or radiated fibrous masses, forming the well-known substance called **asbestos** when pure and in long flexible filaments, and **mountain leather,** &c., when of inferior quality. In the compact state, when its crystalline structure can hardly be detected, tremolite forms a very tough and valuable substance known as **jade or nephrite,** which varies in colour from white to green, and is found in China, Mexico, and New

Zealand. The Chinese images are well known; the hard ones are made from jade, and those which are soft from other minerals closely allied to steatite. The Mexican and New Zealand jades are well represented in most collections by stone axes, arrow heads, &c.

It may be added, to avoid confusion, that one of the minerals used by the Chinese, and known as *jade*, is not compact tremolite, but a compact variety of white epidote called *zoisite*.

The augite minerals form a nearly parallel group to those of which hornblende is a type, and differ from them principally in the angles of the crystals. The varieties of the augite group are as follows:—

Diopside is a transparent, colourless, or light green mineral which occurs in serpentine and granular limestone, but is comparatively rare. It is not a rock-forming mineral, but occurs in veins, and is a silicate of lime and magnesia, with, occasionally, traces of oxide of iron. In the blowpipe flame it is fusible to a white or greyish glass.

Diallage, which is of greater importance as a rock-forming mineral, is a variety of augite. It occurs as an element of some varieties of serpentine, and in the important rock called gabbro, which often accompanies serpentine. It contains more iron than diopside, besides a little alumina, and is easily fusible before the blowpipe to a grey or green bead. It is found in laminar masses, and has generally a nacreous or semi-metallic lustre on the principal cleavage face, and in colour is grey, green, or brown.

Hedenbergite is a black lamellar variety of augite containing much iron, manganese, and zinc, besides lime, and is fusible to a black magnetic bead. It is found in some cavities and veins in the older formations, and has no importance as a component mineral of rocks.

Augite is the best known and most important mineral of this group. It occurs generally in well-formed black crystals, sometimes difficult to distinguish from hornblende, but in the prism of augite the angles of the primitive faces are about 87° and 93°, thus approaching a rectangular prism, whilst in hornblende they are about 124° and 56°, the section of the hornblende prism thus forming a more oblique rhomboidal figure than augite. In sufficiently large crystals these angles can also be obtained by cleavage, as the easy cleavages in both groups are parallel to the faces of the prisms. Another character by which crystals of augite may sometimes be distinguished from hornblende is the brilliant lustre of augite compared with the dull lustre of hornblende.

Augite contains lime, magnesia, iron, &c., and is fusible to a black glass, which is often magnetic. It is common in the volcanic lavas, where it may be seen in the same specimen as a constituent of the paste in microscopic grains, and in well-formed crystals.

Enstatite is very closely related to augite, having nearly the same crystalline form, but belongs to the rhombic system. It is a silicate of magnesia, and, except for its associations, would be more properly included in the preceding group. It is practically infusible or fusible with difficulty on the edges of very small scales. It occurs in some andesites and serpentines, and in the rock called lherzolite.

Bronzite is a variety of enstatite, and is isomorphous with it. It occurs in some serpentines, where it has a lamellar structure, and exhibits a nacreous semi-metallic lustre on the face of easy cleavage. Its colour is brown, pale bronze, or greenish-yellow, and it fuses with very great difficulty, like enstatite.

Hypersthene is also isomorphous with enstatite, but contains as much oxide of iron as magnesia. It is a dark laminar mineral, characterised by a reddish-brown colour, with a cupreous lustre on the cleavage planes. It is fusible to a black magnetic bead, and helps to form the eruptive rock called hypersthenite.

Wollastonite is a silicate of lime, and is a white mineral, rarely crystallised, possessing a nacreous lustre, and occurring ordinarily in lamellar or bacillar masses in granular limestone, granite, or basalt. In some cases it is associated with silver and copper ores, and frequently with garnet. It is fusible with difficulty before the blowpipe.

Hydrous Silicates of Lime and Alumina with their Allies.

The **Zeolites** form a highly interesting group of beautifully crystallised minerals, occurring, in the majority of cases, in cavities or fissures in volcanic rocks, but as they are of no economic importance and are seldom found in mineral veins, much space will not be devoted to their description.

Zeolites are hydrous silicates of alumina with other oxides, usually alkalies, and their specific gravity ranges from 2·1 to 2·9. The softest is scratched by fluor spar, and scratches calcite; the hardest is prehnite, with a hardness between orthoclase and quartz. They are usually colourless or white, or of a very pale pink grey or green, as they contain little or no iron. Even in the darkest of all, a brick-red variety of heulandite, the colour is attributed not to iron, but to a mixture of another mineral.

Prehnite, which is usually pale green, contains a small percentage of protoxide of iron. All zeolites melt and swell up when heated before the blowpipe.

HYDROUS SILICATES OF LIME AND ALUMINA WITH THEIR ALLIES.

(Zeolites—Crystallised Minerals of Secondary Origin.)

Minerals.	Components.	Hardness.	Specific Gravity.	Streak and Colour.	Remarks.
Heulandite, .	Silica, alumina, lime, water	3·5–4	2·2	White to brick-red, streak white	Fusible with intumescence, soluble in acids without gelatinising.
Stilbite .	Silica, alumina, lime, water	3·5–4	2–2·2	White to brown or red	Fuses to white enamel.
Apophyllite,.	Silica, lime, potash, water	4·5–5	2·3–2·4	White to grey or red	Exfoliates and fuses to white enamel, potash flame.
Laumonite, .	Silica, alumina, lime, water	3·5–4	2·2–2·3	White, greyish, yellowish	Gelatinises with acid.
Natrolite, .	Silica, alumina, soda, water	5·0–5·5	2·1–2·2	White, yellowish reddish	Gelatinises with acid, fusible in candle flame.
Thomsonite,.	Silica, alumina, lime, soda, water	5·5	2·3–2·4	White to brown	Fuses very easily to white enamel, gelatinises with acid.
Harmotome,.	Silica, alumina, baryta, water	4–4·5	2·3–2·5	White or grey	Fuses without intumescence, soluble without gelatinising.
Analcime, .	Silica, alumina, soda, water	5–5·5	2·2	White, greenish, reddish	Fuses quietly to glass, gelatinises with acid.
Chabazite, .	Silica, alumina, lime, potash, water	4–4·5	2·1–2·17	White to reddish	In rhombohedrons; intumesces and whitens before blowpipe.
Prehnite, .	Silica, alumina, lime, water	6–6·5	2·8–2·9	Pale green	Fuses with intumescence, soluble in acids without gelatinising. In radiate groups.

Some zeolites are found in gneiss—*e.g.*, heulandite, laumonite harmotome or cross stone, and prehnite. **Harmotome** and

heulandite have been found in the silver mines of Andreasberg; **analcime** in the amygdaloids at the copper mines of Lake Superior; and prehnite occurs, not only in the above copper mines, but also, in New South Wales, with orthoclase and copper ores at Reedy Creek, County Murchison. **Prehnite** is certainly, of all the zeolites, the most interesting in consequence of its associations. It is further mentioned as occurring in crystalline rocks and especially in diorite and other hornblende rocks, from the decomposition of which mineral it is probably derived.

Basalts and lavas containing abundance of zeolites may sometimes be utilised in the arts when, in consequence of the quantity of alkalies present, they are so fusible that they may be easily melted and cast into different forms.

Chabazite is the most common of the zeolites found in basalts. Basaltic lavas, especially when they are in the state of sand and contain a sufficient proportion of alkalies, are used as puzzuolana in the manufacture of cement.

Non-Crystalline Silicates of Alumina.

Clays.—The clays are all products of alteration from other minerals, their composition is variable, and they do not crystallise. The true clays are all plastic and refractory to a greater or less degree, and on these properties their value for industrial purposes depend. Pure kaolin is the type of all the clays.

Such hard earthy minerals as allophane and halloysite may be termed, by analogy, hard clays, since their composition is generally similar to some of the soft plastic clays; but they have not yet been used for manufacturing purposes. They are not plastic, but are derived, in some cases at least, from the decomposition of felspathic rocks, and are often found in mineral deposits.

The presence of alkalies in clay is objectionable, as it renders them fusible, as also do many other oxides. Iron is not only objectionable on the score of fusibility, but also as a colouring matter. The presence of too large a proportion of water, carbonic acid, or organic matter causes clay to contract under the action of fire, and the same result will ensue if the clay is partially fusible. Contraction may also arise from the mechanical arrangement of the particles, and of two clays having the same chemical composition, both of which contain a certain percentage of free silica, the finer one will contract more than the coarser, in which the particles are preserved from that close contact which is necessary for their ready combination and fusion.

The soft clays are divided into **kaolin or porcelain clay,**

which is nearly pure, and is derived from the decomposition of felspar in pegmatite or granite; **plastic or pottery clay,** not so pure as kaolin; and **bole,** containing a great percentage of oxide of iron. **Fuller's earth** is a kind of clay used for freeing wool from fatty matters. It is not easily made into a paste with water, and its application is therefore limited to the above purpose, for which it is of great value.

CHAPTER IV.

PRECIOUS STONES AND GEMS.

THE minerals which are used for ornamental purposes are mostly of considerable hardness, and capable of receiving a high polish. They vary greatly in their chemical composition, but are best divided by their hardness into two groups, viz., those which are harder than quartz, and those which are not harder than quartz.

HARDER THAN QUARTZ.

Diamond is pure carbon. Its hardness, specific gravity, and peculiar lustre, due to its high refractive power, have been already referred to. It will be readily recognised by the prospector who has once seen it in the rough, if simple tests are applied, for diamond will scratch sapphire. The gem prospector should always carry with him some pieces of sapphire, topaz, and rock crystal, as well as a diamond.

In its natural repositories, diamond is not always readily rocognised by its brilliancy, and it is often encrusted with a black coating, or cemented with ironstone; but its greater weight will cause it to settle to the bottom of a tin dish or sieve when washed with other non-metallic minerals of the same size; and, if the dish or sieve be turned over suddenly, the diamonds will remain on the top of the heap, which should be carefully picked over.

Dana says (*System of Mineralogy*, 5th edition)—"The diamond appears generally to occur in regions that afford a laminated granular quartz rock called *itacolumite*, which pertains to the talcose series, and which in thin slabs is more or less flexible. This rock is found at the mines of Brazil and the Urals, and also in Georgia and North Carolina, where a few diamonds have been found. It has also been detected in a species of conglomerate

composed of rounded siliceous pebbles of quartz, chalcedony, &c., cemented by a kind of ferruginous clay."

In some of the schistose rocks of Brazil, above alluded to, it is admitted that the diamond exists *in sitû*, or in the rock in which it was formed; and M. Gorceix states that these rocks are traversed by veins of quartz with rutile, tetrahedrite, oligiste, and martite, the two last being varieties of hæmatite.

In the Transvaal the diamond has been traced to its parent rock, a kind of serpentine, which occurs as huge dykes or necks of igneous rock which have come to the surface, but have not apparently overflowed the lip of the vent or crater, and, according to Mr. Dunn, a geologist at the Cape who has devoted much time to the study of the diamond and gold deposits of this part of the world, these so-called "pans" are local depressions in the flats, and are sometimes as much as three miles in length He also states that when the eruptive rock has been removed the walls of the cavity exhibit horizontal beds of shale, their edges being turned up along the line of contact with the eruptive rocks. The upper beds are, in some instances, formed of grey, pink, or yellow shales with fossil remains (Saurians); the lower beds, from 50 to 150 feet thick, consist of black carbonaceous shales. So combustible are these shales, that when accidentally ignited they have been known to burn for over eighteen months. In this serpentine diamonds are generally found crystallised in octahedra and some of the allied forms.

In Borneo diamonds are said to occur in a matrix of serpentine, and in New South Wales and at Beechworth, in Victoria, good diamonds, although small, are found in alluvial deposits in great numbers. Some of these deposits have of late years received a good deal of attention, and may eventually prove of considerable value. Diamonds have also been worked in alluvial deposits on the Vaal River in South Africa, at Golconda in India, and other places; indeed, with the exception of the mines of the Transvaal, in which the stones occur *in sitû* in serpentine (as already said), all the important diamond fields of the world have been alluvial deposits.

The occurrence of diamonds of different colours affords a remarkable illustration of what has been said about the colours of minerals. As pure carbon, diamond is colourless, as also are the microscopic diamonds artificially produced by an electric current; but in nature the stones are of different colours, which are imparted to them by a very small proportion of foreign matter.

The yellow and grey tints decrease the value of the diamond;

but red, blue, and green varieties, on the contrary, are so rare, that when diamonds are so coloured their value is considerably greater than if perfectly colourless. For instance, the best blue diamond known (44 carats) is estimated at double the calculated value of a good colourless diamond of the same size, viz., £30,000.

In Borneo a kind of black diamond is found which is very highly prized in consequence of its exceptional lustre and rarity; it is even harder than the ordinary diamond.

In Brazil another variety of black diamond, called "bort," which is rough and without lustre, and somewhat resembles the deposit of gas retorts in appearance, is found in quantity, and is used for diamond drills. It sometimes occurs in masses as much as 8 ozs. in weight, and is as hard as the ordinary diamond.

Octahedrite, a mineral occasionally found with diamond, is mentioned under rutile, and is sometimes so splendent as to be mistaken for diamond itself. Diamond should also be compared with white zircon, the lustre of which is also adamantine.

The diamond always occurs as a constituent of rocks or in alluvial deposits and never in lodes. It is principally valued on account of its hardness and high refractive power, being the most valuable ornamental stone. It is also largely used in rock boring drills; and diamond dust is of importance for polishing purposes.

Corundum (sapphire, ruby, &c.).—A number of hard stones of various colours and known by different names belong to this mineral species; they are all essentially composed of alumina. The most common of these gems is *blue corundum* or *sapphire*, which is very frequently found associated with alluvial gold in Australia.

Green varieties, called *Oriental emeralds*, also occur with sapphires, sometimes in considerable numbers, but seldom of a good colour, the most common tint being that of water worn bottle glass which may be so often seen on the sea shore. When pure, and of an emerald colour, they are of a great value, both on account of their hardness and rarity.

Yellow corundum is called *Oriental topaz*, and, being harder than topaz itself while of the same colour, has a greater value. The violet variety is called *Oriental amethyst* and is not common.

Red corundum or *ruby* is next to diamond in value; indeed, a ruby of 3½ carats when perfect is even more valuable than a diamond of the same size. A ruby of 4 to 6 carats in weight is

a great rarity and is worth forty or fifty times as much as the best sapphire of the same weight.

Black corundum is often met with; like emery (which is only an impure variety containing more iron), it is useful for cutting and polishing stones of less hardness than itself. *Emery*, which is largely used for polishing purposes and for the manufacture of emery wheels (now so largely used in machinery works), is the coarsest and commonest variety of corundum; it contains from 10 to 50 per cent. of magnetite and its abrasive power is about half that of sapphire. Most of the emery of commerce comes from Naxos or Asia Minor. It is found in Asia Minor near the surface like a bed of conglomerate resting upon limestone, and it is roughly hand picked on the mines. It is mined by blasting, the bore holes being made in the joints of the rock which are frequently filled with calcite; sometimes also it is worked by firesetting, although this is said to deteriorate the quality.

The fine varieties of corundum have been chiefly obtained from alluvial deposits; they have rarely been traced to their parent rock and have never yet been found in a matrix from which it would pay to extract them, as is the case with the diamond in the Transvaal and the emerald in Peru. In certain parts of New South Wales, corundum is said to occur in basalt with olivine; in alluvial deposits it is found with other hard stones and with tin, gold, &c.

The hardness of this mineral, which is next to diamond, should make it easy always to distinguish; so far as the sapphire is concerned the colour is quite distinctive. Numerous mistakes, however, have been made about the ruby, and it is no uncommon thing for zircon and garnet to be mistaken for it, notwithstanding the easy means of discrimination afforded by the respective hardness of the different minerals.

Dana says (*System of Mineralogy*, 5th edition)—"Corundum is associated with crystalline rocks, as granular limestone, or dolomite, gneiss, granite, mica slate, chlorite slate." A species of felspar with oblique cleavages, called anorthite or indianite, is said to be the gangue of corundum in the Carnatic, India, with garnet, cyanite, and hornblende. At Barsowski in Russia a granular variety of anorthite is said to occur in the auriferous sand as the gangue of the sapphire.

Chrysoberyl comes next in hardness to corundum. It is not transparent, but translucent, and exhibits a play of colours in different shades of green, like a cat's-eye; sometimes a bluish opalescence is to be seen internally.

In alluvial deposits it occurs as rolled pebbles, and in the Ural mountains is found *in situ*, in peculiar star-like groups of crystals, in mica slate associated with beryl and phenakite. It is composed of alumina and glucina.

Spinel is an aluminate of magnesia, and includes several varieties, of which the red variety, spinel ruby, is generally meant when spinel is spoken of as a gem. A variety, which contains a fair proportion of iron and is sometimes called black spinel, is referred to under the name of pleonaste as a stone often found with alluvial tin.

Spinel rubies generally have a dull bluish tinge, which places them far below the true ruby in point of value; they can readily be distinguished by their lesser hardness even when in colour they rival the more valuable gem.

Green and blue varieties of spinel also occur. The *blue variety* is very inferior to the sapphire, even when of very good colour; and *green spinel* is more a curiosity than a gem. It occurs in octahedra when not waterworn.

Red spinels are sometimes found in alluvial deposits with gold, but they are generally very small; and they have occasionally been found in sandstone, but were probably derived from igneous rocks. They are also said to occur imbedded in granular limestone and with calcite in serpentine, gneiss, and allied rocks, as also in cavities in volcanic rocks.

Topaz is a silicate of alumina with fluorine; and its hardness is little less than that of spinel ruby.

White topaz is common as waterworn pebbles in alluvial deposits associated with gold, and has an easy and characteristic cleavage parallel to the base of the prism. It is sometimes sufficiently brilliant to be valued as a gem, especially when well cut; but it is not to be compared with a well cut diamond.

The *pale blue* variety is of value for cutting into large stones for brooches; specimens are occasionally found of several pounds weight.

Topaz of a beautiful *sherry* colour occurs in Brazil. Specimens of this, when heated, become pink, when they are known as burnt topaz. A lighter coloured variety is found in the tin mines of Saxony, and is said to have been found in Tasmania.

The *yellow* varieties are cut as gems; although not very valuable they have considerable brilliance and look very well.

Emerald and Beryl are chemically the same, being composed of silica, alumina, and glucina.

The varieties known as *beryl* are generally opaque or nearly so, and are light green or yellowish in colour. Large crystals, six-

sided prisms, are common in veins of pegmatite traversing granite, and are also found imbedded in quartz.

A pale green or light blue transparent variety is known as *aquamarine*, and is sometimes used as a gem, but has no great value. It is sometimes mistaken for topaz, but is neither so hard nor so heavy; nor does it, like topaz, become electric by friction.

According to lapidaries, *emerald* is a little softer than beryl, but its rich and characteristic green colour makes it a gem of great value. It is found in mica schists in Siberia and Salzburg; and in clay slate with concretions containing Cretaceous fossils in Granada. The emeralds from the last locality are especially noted for their beauty of colour, but the largest crystals have been obtained from Siberia. Some emeralds have been found in a vein traversing granite in New South Wales, and minute specimens in a syenitic gneiss at Dusky Sound, New Zealand.

Phenakite differs from emerald in composition by not containing alumina nor the traces of green colouring matter. It is generally colourless, but rarely wine yellow, so that it is difficult to distinguish from topaz, their hardness being also the same. Phenakite is, however, lighter and considerably rarer. It occurs in the Ural in mica schists with chrysoberyl and emerald; and elsewhere, associated with other minerals.

Zircon is a silicate of zirconia. The crystals are of various shades from colourless and transparent, when they are sometimes mistaken for diamonds, to yellowish, green, brown, and red. The smoky white varieties are known as *jargons*, the transparent red varieties as *hyacinths*, and the grey and brown forms as *zircons*.

This mineral is remarkable for its brilliant lustre, which approaches that of the diamond, but it is not of much value. It has been found in granite and other crystalline rocks, and occasionally in volcanic rocks.

Dichroite or Cordierite is a silicate of alumina, iron, and magnesia. It is not commonly used as a gem; it is of more value as a curiosity, in consequence of its showing two different colours when light is passed through it from different directions, than on account of its real beauty. It has been named *dichroite* from this property.

It exhibits various shades of blue in one direction, and a brownish-yellow or yellowish-grey in a direction at right angles to the first. It is known to jewellers as "sapphire d'eau." It occurs in granite, gneiss, hornblende, chlorite, and talcose schists, and allied rocks, with quartz, orthoclase, albite, tourmaline,

hornblende, andalusite, and, sometimes, beryl. It is also found in volcanic rocks, and is often decomposed.

Tourmaline will be mentioned as a mineral accompanying tin. There is a remarkable instance of its occurrence with gold in the New Mount Morgan mine in Western Australia, where gold is commonly disseminated through the joints of the crystals. It is a boro-silicate of alumina and other oxides, and contains fluorine.

There are many varieties, but those used as gems are either red, green, or blue. The first is termed *rubellite* by mineralogists, or simply *tourmaline* by jewellers; the green and blue varieties are known as *Brazilian emerald* and *sapphire* respectively, and in Brazil they are worn by dignitaries of the church.

Tourmaline is usually found in granite, syenite, gneiss, mica schist, chlorite schist, or talcose schist, as also in diorite, dolomite, granular limestone, &c. The most common variety, *schorl*, is black. It is easily recognised, as it occurs in long needle-shaped crystals, which become electric when heated.

Garnet is also alluded to as a mineral which often accompanies tinstone, or is likely to be mistaken for it; only those varieties used as gems will be mentioned here. The colour is blood- or cherry-red, passing to various shades of crimson, purple, and reddish-violet on the one hand, and to orange, red, and hyacinth-brown on the other.

Unlike other red stones, garnet is not readily cut in faces, and is generally cut as carbuncles or, in other words, with a smooth oval surface. In this form the best qualities display brilliant fire-red flashes of light. The best garnets used as gems belong to the varieties called *almandine* and *pyrope;* they are chiefly obtained from Syria and Bohemia, and are called in the trade "Syrian" and "Bohemian garnets."

Besides the red-coloured pyrope and almandine, there are some other varieties of very different colours. A green garnet, called *ouwarowite*, is coloured by oxide of chromium; a black garnet found in crystalline schists is called *melanite*, and contains much iron.

Not Harder than Quartz.

There are many varieties of quartz which claim some attention as ornamental stones, all of which consist of silica.

Rock Crystal occurs crystallised in six-sided prisms with pyramidal ends; it is perfectly clear and transparent, and is used both for optical instruments and for ornamental purposes.

It is sometimes found in crystals of enormous size, several weighing from 8 to 10 cwts. having been recorded; and it is reported that about a century ago a drusy cavity was opened at Zinken from which 50 tons of rock crystal were obtained, which realised £60,000.

Smoky quartz, or Cairngorm, has a smoky yellow to brown tinge. The colour is probably due to titanic acid, as crystals containing rutile are generally smoky. It is called *cairngorm* from the locality in Scotland of that name.

Citrine quartz, or False Topaz, which is yellow in colour, is easily distinguished from topaz, which it resembles, by the absence of cleavage and the difference in hardness.

Amethyst quartz is the most highly valued of the coloured varieties. It may be described as clear and of a purple or violet colour. It is usually found in cavities in volcanic rocks.

Chalcedony generally occurs in stalactitic or concretionary masses, and is usually whitish, yellowish, or yellowish-brown, rarely pure white. This variety, in common with those which follow, is translucent.

Agate is a variegated chalcedony alternating with bands of quartz, in which the colours are cloudy or banded, but rather dull and not showing any sharp contrast one with the other.

Onyx differs from agate in being distinctly banded in well-contrasted shades, such as black and white, or brown and white, but most of the black varieties are artificially stained.

Sardonyx is a brownish-red or orange variety of agate.

For agate to become an important article of trade it must be found in large quantities, and in rocks so much decomposed that the process of extraction would be an easy one. Agates are mostly found in cavities in volcanic rock, where they have been deposited by water.

Carnelian is of a clear blood-red or light-red colour, but this colour is said to be produced in India by burning, it being due to oxide of iron.

Chrysoprase is of a beautiful apple-green colour, due to oxide of nickel. In a warm, dry place the colour of chrysoprase is destroyed, but it can be again restored by keeping it damp.

Plasma is an olive-green chalcedony.

Heliotrope or Bloodstone is plasma traversed by small veins or specks of red jasper.

Under the names of *moss agate* and *dendritic agate* are included those varieties in which dendritic crystals of metallic oxides occur, a common mode of crystallisation for oxide of manganese.

Most specimens of petrified wood, when there is no earthy or clayey matter present, are transformed into chalcedony.

Cat's Eye is another translucent variety of quartz, but, unlike chalcedony, it is crystalline, but not amorphous. A variety containing fibres of asbestos is sometimes incorrectly called "crocidolite." It is yellowish-green in colour, with golden and green streaks of light, and has a silky appearance, due to the fibres of asbestos. The original fibrous crocidolite is of a fine blue colour. This stone is well known as occurring in the diamond districts of the Transvaal, and is also found in Germany, Ceylon, and elsewhere.

Opal is silica in an amorphous condition, usually with some water, and includes not only noble opal, but also those common varieties which are of no value. Fossil wood often consists of hydrous silica.

The opal used as a precious stone is translucent, and has a beautiful play of different fire-like colours—red, yellow, green, and blue being conspicuous in some varieties; while in others, one of these colours is prominent, the rest being less distinct.

Perfect opals are very valuable, but their value is greatly enhanced when they are set, since the operation of cutting is very difficult, in consequence of their brittleness. They are usually found in cavities in amygdaloidal rhyolite and some other lavas.

Orthoclase, Oligoclase, and Labradorite.—Some varieties of orthoclase and oligoclase contain minute flakes of other material, are iridescent and exhibit a beautiful play of colours. They are called *sunstone* and *moonstone*, and are occasionally set in brooches, but are too soft for rings. They are chiefly obtained from India, America, and Ceylon.

Iridescent Labradorite, which is chiefly obtained from the coast of Labrador, is sometimes found in blocks of large size and of varying colours—violet, blue, &c. It is used for decorating artistic furniture, and is sometimes cut for pins, &c.

A beautiful variety of orthoclase known as *Amazon stone* occurs as large green crystals in Siberia and the United States. It would form a pretty ornamental stone, but is not transparent.

Olivine or Chrysolite, which is also known as *peridot*, is a silicate of magnesia coloured with a small proportion of iron; its usual colour is bottle green of various shades. It is not so hard as quartz and but little harder than glass, besides which it is brittle and therefore of very little value. It is an essential constituent of basalt, and occurs in serpentine. In New Zealand and New Caledonia it forms a massive rock, which frequently contains chromite, and has been named *dunite*.

Epidote is a silicate of alumina and lime, with small proportions of iron and water. It occurs crystallised in long prisms of an olive-green colour in one direction and yellow or brown in another; so that, like cordierite, it is dichroic. It is more a curious than a precious stone; its lustre is vitreous, and it is too dark for ornamental purposes. It is of common occurrence in many crystalline rocks, especially those which are hornblendic, and in serpentine; and it often accompanies beds of magnetite and hæmatite.

Kyanite is a silicate of alumina, generally of a light blue colour, but also white, grey, or green. It occurs in long, thin, blade-like crystals imbedded in mica schists and gneiss. It is of no value as a precious stone.

Vesuvianite or idocrase is a complex silicate of alumina and other oxides, and is allied to garnet, but crystallises in different forms; it resembles tinstone, from which, however, it can be easily distinguished by its fusibility. It has a vitreous lustre and a hardness of 6·5, but is of no value as a gem. It is found in volcanic rocks at Vesuvius and in crystalline schists and gneiss in many localities.

Andalusite has the same composition as kyanite, but crystallises in different forms, besides having, when coloured, a reddish tinge. The variety *chiastolite* occurs as small white rod-like crystals imbedded in slate, and exhibits the form of a dark cross due to impurities in its sections. It is a little harder than quartz, and its lustre is vitreous.

Turquoise is a hydrous phosphate of alumina. It is amorphous and opaque. The best quality, the Persian turquoise, is of a beautiful sky blue colour. Odontolite, called by jewellers "turquoise of newrock," is fossil bone, coloured by copper. It is of far inferior quality to the true turquoise, and is easily decomposed; when the unpolished surface is carefully examined the structure of bone can be seen. Odontolite occurs chiefly in cave deposits; while true turquoise is found in sandstones, where it is found in seed-like groups.

Ultramarine or Lapis Lazuli.—This beautiful stone is blue; opaque or semi-translucent; and is often traversed by veins of pyrites. It is a very complex mineral chemically (if, indeed, it must not be regarded as a rock), consisting of silicate of alumina, with soda, lime, sulphur, chlorine, &c. So long as the pigment which bears its name was obtained solely from this source, the price of the colour was enormous; but since it has been manufactured artificially the price has been greatly reduced, and ultramarine can now be obtained at a fraction of the price formerly paid for it.

Although its ally, hauyne, is crystallised, lapis lazuli occurs in a massive state, being found in crystalline limestone on the banks of the Indus; and in granite, in Persia, China, and Siberia. It is used in mosaic work, and costly vases are made from it; but it is also worn as a jewel.

Boracite.—This mineral, though not a gem, is included here on account of its hardness, which is that of quartz. In the table for the determination of minerals it is placed with tourmaline, which it resembles by containing boron, and also in becoming electric when heated. It contains chlorine, and, mixed with oxide of copper, will colour the flame azure blue. It is rare, but is found in small white crystals with gypsum and rock salt.

COLOURS OF PRECIOUS STONES.

Name.	Colourless.	Red.	Deep Yellow.	Pale Yellow.	Bottle-Green.	Green (various).	Emerald.	Pale Blue.	Blue.	Indigo.	Violet.	Brown.	Brown-Yellow.
Diamond,	×	R	...	×	...	R	...	...	R	...	...	...	...
Corundum,	×	×	×	...	...	...	×	...	×	...	R	...	...
Chrysoberyl,	...	...	...	...	...	×	...	...	...	...	...	...	...
Spinel ruby,	...	×	...	...	...	×	...	...	R	...	...	...	...
Topaz,	×	...	×	×	...	...	...	×	...	...	...	...	...
Emerald, including beryl,	...	...	...	...	...	×	×	×	...	..	...	...	...
Zircon,	×	×	...	...	...	...	...	...	...	...	...	×	×
Cordierite,	...	...	...	...	...	...	...	...	...	×	...	×	...
Phenakite,	×	...	×	×	...	...	...	...	...	...	...	...	×

R means "rare."

SCALE OF HARDNESS FOR PRECIOUS STONES.

5	Apatite (not a precious stone); scratched by steel.		
5·5	The hardest glass (imitation gems are still softer),		Opal.
6	Orthoclase; scratched by hardened steel,		Opal.
	Turquoise; " " "		Opal.
6·5	Olivine or peridot,		Garnet and varieties.
7	Quartz, amethyst, cairngorm,	Tourmaline, cordierite,	Garnet and varieties.
7·5	Zircon, garnet,	Tourmaline, cordierite,	Garnet and varieties.
8	Topaz, spinel ruby, emerald, beryl, phenakite.		
8·5	Chrysoberyl.		
9	Corundum (sapphire, ruby, oriental emerald, oriental amethyst, oriental topaz).		
10	Diamond.		

SPECIFIC GRAVITY OF GEMS.

Agate,	2·5 to 2·8	Hauyne,	2·4 to 2·5
Amethyst,	2·5 ,, 2·8	Heliotrope,	2·5 ,, 2·8
Andalusite,	3·1 ,, 3·2	Kyanite,	3·5 ,, 3·7
Beryl,	2·6 ,, 2·8	Labradorite,	2·68 ,, 2·74
Bloodstone,	2·5 ,, 2·8	Lapis lazuli,	2·38 ,, 2·42
Boracite,	2·9 ,, 3·0	Oligoclase,	2·64 ,, 2·68
Cairngorm,	2·5 ,, 2·8	Olivine,	3·3 ,, 3·5
Carnelian,	2·5 ,, 2·8	Onyx,	2·5 ,, 2·8
Cat's eye,	2·5 ,, 2·8	Opal,	2·0 ,, 2·2
Chalcedony,	2·5 ,, 2·8	Orthoclase,	2·53 ,, 2·58
Chrysoberyl,	3·7 ,, 3·8	Phenakite,	2·97
Chrysolite,	3·3 ,, 3·5	Plasma,	2·5 to 2·8
Chrysoprase,	2·5 ,, 2·8	Quartz,	2·5 ,, 2·8
Citrine,	2·5 ,, 2·8	Ruby,	3·9 ,, 4·2
Cordierite,	2·5 ,, 2·7	Sapphire,	3·9 ,, 4·2
Corundnm,	3·9 ,, 4·2	Sardonyx,	2·5 ,, 2·8
Crocidolite,	3·2 ,, 3·3	Spinel,	3·4 ,, 4·1
Diamond,	3·5 ,, 3·6	Topaz,	3·4 ,, 3·6
Dichroite,	2·5 ,, 2·7	Tourmaline,	3 ,, 3·6
Emerald,	2·6 ,, 2·8	Turquoise,	2·6 ,, 2·8
Epidote,	3·2 ,, 3·5	Vesuvianite,	3·3 ,, 4·0
Garnet,	3·5 ,, 4·3	Zircon,	4·0 ,, 4·7

CHAPTER V.

STRATIFIED DEPOSITS.

Those classes of mineral deposits which come under this head have been formed at the same time as the rocks with which they are interstratified, and, indeed, may be looked upon as rocks themselves.

Such substances as slate, marble, and the various building stones, which are quarried; coal, some deposits of ironstone, rock salt, and gypsum, which are either quarried or mined; and, lastly, rocks which are impregnated, to a greater or less extent, with metallic minerals, come under this group.

Regarding those substances which have to be quarried, such as slates and the various building stones, it is not proposed to enter into any description, while the other two groups require separate treatment, because the former (of which coal may be taken as a type) will be worked so that the greatest quantity of material will be removed; the latter, so that only that portion be taken which will be of a remunerative character.

Coal.—It will be of advantage in the first instance to study the manner in which coal has been formed, and thus arrive at some of the principles which govern its distribution.

That coal is of vegetable origin may readily be proved by examining a thin slice of that substance under a microscope, when the tissues of plants can be more or less perfectly seen; but in most cases there are two kinds of structure visible, one the so-called structure of mineral charcoal, resembling charred wood, in which the vegetable tissue cannot be recognised; and the other, composed of round cell-like bodies.

In recent years it has been shown that, in many cases at all events, the bituminous or volatile matters in coal are due to these round cell-like bodies, and these have been traced to the resinous spores of plants which are allied to the club mosses of the present day; but unlike these, which seldom grow to more than a few inches in height, the plants to which these spores belonged grew to a very great height, and the climate and conditions generally must have been extremely humid.

It is now generally considered that coal seams were formed on the sites where the plants from which they are derived grew, and, therefore, that the bed of underclay which is frequently found below the coal was the soil upon which these plants grew; but in some few cases coal seams may have been formed by vast accumulations of drift wood. That most seams of coal were formed *in situ* is borne out, however, by the occurrence of roots in this under clay.

A careful examination of any section in which seams of coal occur demonstrates the fact that the rocks with which they are chiefly associated are alternating beds of shale and sandstone, with occasional beds of fireclay and ironstone. It is not at all unusual to find a thickness of several hundred feet of these rocks, including several seams of coal of varying thickness and quality, some of which could be worked to advantage, while others are not of sufficient value to pay for mining.

It is seldom the case that these shales and sandstones contain marine fossils; remains of plants and occasional fresh-water shells are the only fossils that occur in them, and there can be no doubt that they were deposited under conditions which allowed of the growth of dense forests, of their submergence below fresh-water areas, and of their subsequent elevation when fresh forests grew, which in their turn were altered to coal. Subsequent depressions on a larger scale have in many cases submerged these coal-bearing beds below sea-level, and rocks containing marine fossils are then found overlying the coal-bearing series.

It will be perfectly evident that with the mode of formation described the extent of valuable seams of coal is not necessarily coterminous with the shales and sandstones with which they are interstratified. The extent of the coal seams will depend to a great extent upon the local conditions which prevailed at the time of their formation; and whereas the conditions of soil and climate may have been identical over very wide-spread areas, in which case the coal will be of uniform quality and thickness for great distances, it may equally well prove that these conditions were very local, and consequently that the seams vary much in short distances, thinning and deteriorating in passing from one property to another.

It is seldom the case that seams of coal are found in an absolutely horizontal position, and so, if they have any dip at all, they are generally to be found outcropping somewhere or other. These outcrops may be, as in mountainous countries, represented by a cliff, frequently with a hard sandstone forming a scarp, with the softer coal underlying it, as in the accompanying sketch, in which case the coal can easily be tested and measured with very little work; or, as in flat or undulating country, where the rocks have been much decomposed, the outcrops may be obscured by surface soil, and then more judgment is necessary in order to decide what work should be done.

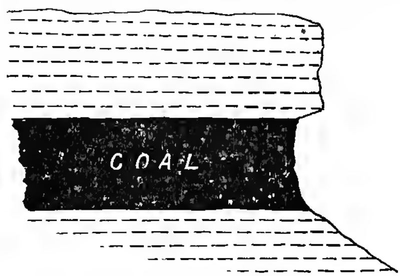


Fig. 5.—Section.

The following sketch (Fig. 6) will illustrate the conditions alluded to. Where these prevail, some information regarding the strike and dip of the strata and the probability of coal existing can generally be gained by an examination of creek beds or any outcrops of rock which exist; after which, a careful examination of the soil will frequently reveal small pieces of coal in it or, possibly, only a black sooty-like smudge in the soil, which will afford some indication of the best places in which to sink small trial holes in search for coal.

Surface prospecting is of the greatest value for deposits of this class, and should always be undertaken before any more expensive methods of testing the ground are adopted. Having demonstrated the fact that a seam or seams of coal exist on any

property, the next point that will have to be considered in forming any idea of the extent of these coal seams is, to what movements have the rocks been subjected; what, in fact, are the angles of inclination or dip of the different beds? Knowing that seams of coal are stratified deposits, or have been formed during

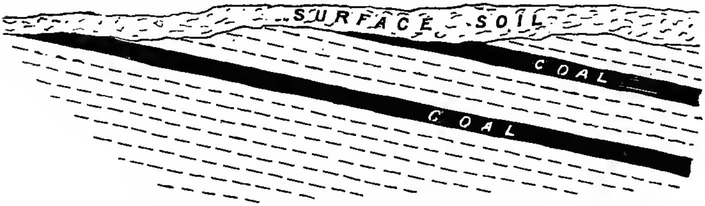


Fig. 6.—Section.

the same geological period as the rocks in which they occur, it will be certain that the coal seams themselves have been subjected to the same movements as the rocks, and having once settled the position of a coal seam in a section, any further observations of dip or strike may just as readily be taken in the rocks which crop out at the surface as in the coal seam itself.

To illustrate this by a section; if it is supposed that a coal seam has been found cropping out at the surface in a cliff as at *a* (Fig. 7), and dipping in the direction indicated, the thickness of

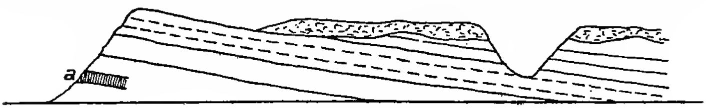


Fig. 7.—Section.

the beds to the summit of the cliff can be measured, and then the upper bed traced along the surface towards the dip. Taking advantage of every outcrop of rock which is to be seen, and noting the dip of each, an exact idea can be formed of the course of the coal and the depth at which it will be found at different points. If the dip was uniform, as shown in the section, this would be very simple; but if, on the other hand, the dip and strike changed at different places, the surface would have to be studied very carefully in order to arrive at these conclusions.

In the following plan (Fig. 8) let (*a*) be a seam of coal, cropping as shown, and (*b*) a bed overlying it, also cropping at the places marked, and dipping as shown by the arrows. In this case, the

main body of coal would lie in the direction indicated by the large arrow, and coal struck along this line could be worked to the rise in three directions.

A surface study of the ground may thus be of the greatest value in determining in what direction boring operations can best be carried on, and may frequently save a great expenditure in useless boring, since it is not a very unusual thing for bore-

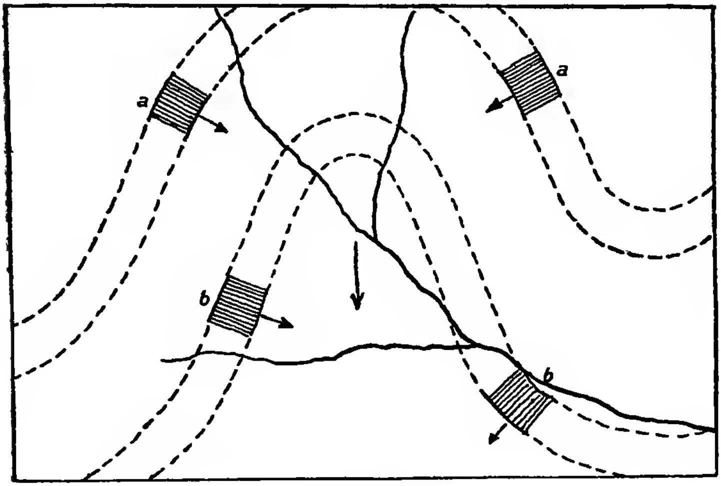


Fig. 8.—Plan.

holes to be sunk when the same information could be better obtained by a surface study of the ground.

This surface prospecting, however, will not inform us what the thickness of the coal seams may be in any particular area, nor give us any notion of their quality. Having by surface work arrived at a conclusion as to the distribution of the beds, boreholes, situated judiciously so as to prove the thickness and quality of the seams, must be put down and an accurate knowledge regarding them thus obtained.

It is an old and true saying that "a colliery well bored is half won"; but even boreholes will not give notice at the outset of all the troubles which may be met with in the workings. There may be small or even large faults which have disturbed the seams, and may thus give rise to a large amount of dead work; or there may be bands of stone and partings, formed during the

deposition of the coal by streams which carried a certain amount of sediment with them; or "wash outs" may occur where the coal has been completely carried away by running water, and its place filled in with sand or gravel; or the coal may even be cut out by dykes of igneous rock, which have been forced up from below, as at Newcastle and Illawarra in New South Wales. All matters such as these can only be determined in the workings, and we must always be prepared to find a fair proportion of such difficulties to contend with and overcome.

Surface prospecting and boring can, however, determine the area of the coal-bearing rocks in a certain district, and can demonstrate the existence of workable seams of coal in these deposits; beyond this the prospector can hardly be expected to go. There are always elements of uncertainty in mining, and although coal mining is perhaps the most certain of all, it is not free from disappointments. The quality of coal varies considerably, for while some classes are suitable for steam raising and smelting purposes, others have a much less extended use; but these characters will be referred to in a later chapter.

In working coal it must be borne in mind that everything depends upon local conditions, the thickness of the seams; the presence or absence of bands interstratified with the coal, and the nature of the roof and floor; and it is worth while considering a few points now which bear upon the question.

Seams of coal not more than 18 inches thick can be worked to advantage under special circumstances, but these must all be favourable. The roof and floor must be good; the inclination of the seam small; there should be facilities for driving coal-cutting machinery at a cheap rate; wages should be cheap and the sale price of coal comparatively high; and, especially, there should be no competition with thicker seams under as favourable conditions in the neighbourhood.

Seams are worked up to 50 feet, and even more, in thickness; but no special advantage exists in working a seam over 6 ft. or 7 ft. thick; as, although more coal can be won in a given area, the expenses of supporting the roof and the difficulties of ventilation militate against cheap working. In the early history of a district the cost of working coal is generally at a minimum and even when wages are high, as, for instance, in the United States, there are many cases where outcrop coal is worked at about 4s. per ton; while in England, with lower wages, the cost is often 7s. per ton (or even more) when worked from shafts, with pumping and surface charges to be considered.

The presence of bands or layers of shale or stone in a coal seam is sometimes very prejudicial to the working, indeed, at times will make an otherwise valuable seam useless; but, in other cases, where the bands are fairly large and separate easily from the coal, the stone from them can be used to build pack walls in the mine and they are no serious inconvenience.

Iron Ores.—Deposits of ironstone occur under somewhat similar conditions to coal, but they are much more irregular in their extent. They are frequently found associated with the coal measures, but quite as often are interstratified with beds in which no coal is present. Most stratified deposits of iron are either carbonate of iron, known as *spathic iron ore;* carbonate of iron mixed with some carbonaceous matter, known as *black band ironstone;* or a hydrous oxide of iron, known as *brown iron ore.* There are also deposits of red hæmatite, the anhydrous oxide, but these are of rarer occurrence.

By far the greater quantity of ironstone mined is brown iron ore, of which the extensive deposits of Bilbao in Spain may be taken as a type. The ores are mined and picked so as to produce as high a percentage of iron as possible, and are sold on the basis of 50 per cent. iron, so much per unit being paid for each per cent. above this. The prices naturally vary somewhat, but from 4d. to 6d. per unit for ores of 50 per cent. and over, delivered in Wales or the North of England, may be taken as about their value. It will be evident that the margin of profit in working this ore is slight, and that conditions have to be very favourable to allow of a deposit being worked to advantage.

Rock Salt and **Gypsum** also occur under somewhat similar conditions, but hardly merit any special remarks here, although, of course, the salt industry is enormous.

Metallic Ores.—The group of impregnated stratified deposits is well represented on the Continent of Europe by the Bunter sandstone, which in parts of Germany is charged with fine grains of galena, the whole rock at times containing about 3 per cent. of lead; and by the copper slate of Germany in which the impregnated rock yields 2 to 3 per cent. of copper, and is richened at places by veins which traverse it and contain more valuable ores.

It is of importance to note that such deposits as the Bunter sandstone and copper slate have afforded employment to many hundred men for between 200 and 300 years, and so may be looked upon as deposits of very great commercial importance. This also affords another illustration of the fact that very poor

deposits of this sort will pay well to work if the quantity of ore is sufficient.

Gold Deposits.—By far the most important, however, of the impregnated stratified deposits which have yet been found are the so-called *banket beds* of the Transvaal. These beds consist of quartz conglomerates which are interstratified with shales. The remarkable feature concerning them is that the pebbles of the conglomerates appear to be imbedded in a matrix of quartz, which must have been deposited from solution around them; it is in this enclosing quartz that the gold occurs. There are several of these beds lying one above the other and separated by beds of shale. In the neighbourhood of Johannesburg they have been traced and worked for miles along their strike.

The most interesting and valuable fact regarding this deposit is the comparatively uniform yield of the stone; for while, of course, it is not all equally rich, experience has shown that very large areas yield ore which is constantly payable to work, and that by opening the ground on a large scale a constant and steady yield can be maintained. It is difficult to account for the origin of these deposits; and although many theories have been propounded, it is doubtful whether any of them satisfactorily explain the occurrence, for it is not easy to understand how the enclosing matrix of quartz can have been formed unless from siliceous springs which also carried gold; and if this be their source, it is hard to imagine that these springs should have the widespread distribution which would be necessary to explain the phenomena. It is true that some chemical decomposition in inland waters might account for the occurrence, but even this it is hardly possible to investigate at present on the basis of observed facts.

Be their origin, however, what it may, it is certain that the deposits are widespread in the Transvaal, and have opened a field for gold mining such as has never been seen elsewhere, and under conditions which have never before been secured. Instead of the uncertainty of reefs, in which rich shoots of gold are succeeded by barren parts, thus preventing one from forming any estimate of value beyond those portions of the reefs or lodes that can actually be seen, the Transvaal beds have been so developed as to show their continuity and uniformity in such a manner that they have all the elements of permanence possessed by a coal seam.

Their early history, moreover, did not foreshadow the great value they would ultimately acquire; for it was found that by battery amalgamation only a comparatively small proportion of

the gold was saved, and it is due to the cyanide process for the extraction of gold that the success of the Rand mines is due, while it is equally true that the success of the cyanide process is due to the Rand.

In no part of the world has gold mining been carried on upon the extensive scale which is adopted here, and perhaps in no case has capital been so lavishly expended in equipping mines with all the latest improvements, as no expense has been spared when success could be gained by incurring it.

At the present time the Rand mines are yielding over 200,000 ounces of gold every month, approaching a value of £1,000,000 sterling; and there appears no reason to anticipate any immediate falling off in the yield.

No similar deposits to these have yet been found, but the prospector should devote careful attention to testing any similar beds he may meet with. It must be remembered that eminent mining engineers did not attach great importance to these beds when they were first discovered on the Rand, and it is quite possible that similar beds may be found elsewhere. There are certain conglomerates associated with the Carboniferous rocks of New South Wales in which gold has been found; and in Spain it is stated that auriferous conglomerates exist; but in neither case have they been developed.

There are many other cases in which rocks have become impregnated with valuable minerals in the neighbourhood of veins and dykes, which will be referred to under the heading of Irregular Deposits; but there is one case to which attention should be called at this place, viz., the Belubula deposits near Carcoar in New South Wales.

These beds, which crop out close to the Belubula River, rise as a small hill, are regularly stratified, and dip towards the river, as in the following section :—

Fig. 9.—Section.

In a vertical section of about 90 feet, over 50 feet in thickness is composed of material carrying gold.

The auriferous beds are of a fine sandy nature, and are very easily crushed, while the beds with which they are interstratified are of a slaty character, and are stated by some

observers to be very fine grained "laccolites;" the whole series being considered as of igneous origin. There is, however, a very well marked stratification, and the lines of demarcation between the auriferous and non-auriferous beds are well and clearly defined.

The auriferous beds are not uniformly rich in gold, but vary in their gold contents from mere traces to nearly 1 oz. per ton. Some thousands of tons have been crushed in a battery, and are reported to have yielded between 5 and 6 dwts. of gold per ton.

These beds are somewhat heavily charged with soluble sulphates, such as alum, sulphate of iron, &c., which makes it impossible to recover a fair proportion of the gold by ordinary processes, unless the ores are previously roasted.

Working Expenses.—The most important matter for the prospector to bear in mind as regards the occurrence of impregnated minerals in stratified deposits is, that, if it can be shown that these impregnations extend over a considerable area, the conditions of working will be such as to reduce working expenses to a minimum. Under no conditions in lodes can the ore be mined so cheaply; consequently, if large beds exist it is safe to calculate that, working on a large scale, very low returns will pay. It is true that a large initial expenditure will be necessary to equip the mine on such a scale as will allow a margin of profit upon low grade ores, but when this preliminary expense has been incurred the business becomes one of an industrial nature rather than the ordinary mining risk. It is true that very little prospect exists of those sensational returns which sometimes enhance the value of shares in an abnormal manner, but steady profits can be looked for if proper care is exercised in the management.

There is yet one point to which attention should be called when considering the working of stratified deposits generally, whether coal, iron, salt, lead, copper, or gold—viz., that the whole success depends in every case upon a most careful attention to detail. It must be accepted as a principle that the profit per ton of ore mined will be small, and that a little laxness in the management here and there will very soon convert a surplus into a deficit. When it is considered that on an output of 1,000 tons a day a halfpenny per ton represeuts over £600 a year, it will be seen that the most rigid care has to be exercised on small details in order to make this class of mining successful. It is true that this question, perhaps, hardly affects the prospector; but still it should be always present in his mind, for he must

look ahead and be able to decide whether any property which he secures will bear the investigation it is sure to receive before he can reap any profit from his discovery; and a thorough knowledge of the conditions which should prevail in subsequent working is the only way in which he can avoid mistakes and an undue expenditure of time and labour in the early history of a mine.

CHAPTER VI.

MINERAL VEINS AND LODES.

Fracturing of Rocks.—Bearing in mind the numerous movements of elevation or depression to which strata have been subjected since they were originally formed, and the dislocation to which these movements have given rise, it becomes possible to investigate the origin and characters of metalliferous deposit occurring in lodes or fissures in the rocks.

It will at once be apparent that when sedimentary strata in an unconsolidated condition are raised from the sea, tilted from one end, or even folded into a number of anticlinal and synclinal curves, they will still be in a sufficiently plastic condition to adapt themselves to any fresh form which they have to assume. This is the reason why the younger sedimentary rocks seldom contain mineral veins unless they have been hardened rapidly by some local cause. On the other hand, where strata have, during the lapse of ages, become consolidated, and changed from mud, sand, or clay, to shale, sandstone, or slate, either in consequence of great pressure or chemical action ; or where they have been further subjected to the process of metamorphism and thus assumed the characters of quartzites, schist, or gneiss, it will be evident that any further movements of the rocks must be attended by the formation of cracks or fissures traversing them, because they are no longer sufficiently plastic to accommodate themselves to new forms without breaking.

In the present chapter, the manner in which cracks may be formed and the method by which they may be opened to form underground drainage channels will first be considered ; and afterwards some attention devoted to the manner in which the valuable minerals have been brought into the reefs.

Any granitic upheaval, or intrusion of other crystalline rock,

tilts the adjacent beds, and, if these are hard, forms a number of cracks or fissures in them, following a direction parallel to the line of upheaval. These cracks are of two kinds, viz., those which dip or underlay away from the line of elevation, and those which are inclined towards it.

Rocks are of very different degrees of hardness, and, when broken, the line of fracture will vary in angle in the different beds. Prospectors hardly need to be told that this is the case, for they know from their own experience that different classes of rock break very differently when struck with a spalling hammer ; some have a clean straight fracture, others break with curved faces, and others split more readily in one direction than in any other.

It is the varying angle of fracture in different classes of rocks which has been the primary cause of the opening of mineral veins or fissure lodes, as will be demonstrated shortly ; but in the meantime the fact is of the greatest importance to be remembered.

It is seldom the case that the line of elevation is exactly parallel to the line of strike of the beds, since these have generally, while in a plastic condition, been subjected to certain plications. Hence, in by far the greater number of cases, lodes pass through several different belts of strata ; thus a lode, instead of being represented by a straight line on the surface, follows a sinuous course, which is determined by the characters of the rocks through which it passes.

In investigating the history of the formation of lodes it may be assumed that a granitic boss has been forced upwards and has tilted and fractured the rocks resting upon it ; and after this some settlement of the rocks has again taken place before they assumed a stable condition. These movements are attended with results which may be illustrated by the following diagram :—

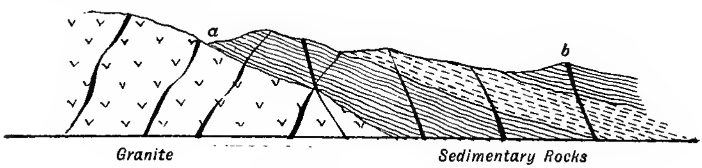


Fig. 10.—Section.

The upheaval forms cracks through the overlying strata from (a) to (b), these cracks dipping away from the line of elevation represented by the granitic boss ; a settling down of the beds

results in a sliding of the rocks on the hanging wall side of the fissure over those on the footwall side of it.

It has already been pointed out that the cracks do not traverse the various beds at a uniform angle, and so, when a sliding takes place of one uneven surface on another, the result will be that certain parts of the lode will remain closed, whilst other parts are opened. This is illustrated in the following sketch :—

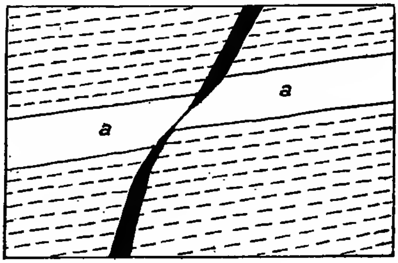


Fig. 11.—Section.

Underground channels are thus opened which are subsequently filled with the various minerals of which lodes are formed.

The opening of fissures in this manner can easily be demonstrated by drawing an uneven line on a piece of paper, tracing this line and allowing the tracing to move on the original. The result will be seen to be that the steeper parts of the lode are opened, while the flatter portions remain closed.

The settling down of the granite boss gives rise to another series of cracks, which underlay towards the line of elevation (as shown in the sketch), and these open in the same manner by the sliding of the hanging wall on the footwall in the granite area, the sedimentary rocks having by this time come to rest.

Lodes.—These movements are attended by the formation of a number of intersecting lodes in the region of *a* (Fig. 11), where the two series of fissures meet; and many secondary lodes might also be formed having a less angle of inclination than the principal fractures; also, since these cracks must terminate at some point or other, cross courses are produced having a direction nearly at right angles to the average strike of the true reefs. These cross courses may be either barren or productive, as the conditions of the country are favourable or not. The ultimate result of these movements is to form a number of underground

galleries through which water can circulate freely, and these subterranean waters deposit the various minerals found in lodes.

It will be evident from an inspection of the following sections that in a simple fissure the steeper parts of the lode will remain open, the flatter portions being closed; but in those secondary fissures, which junction with the main lodes, the reverse will be the case, because the wedge-shaped block between the two fissures would be but slightly displaced, while the block of country which formed the hanging wall of the main lode

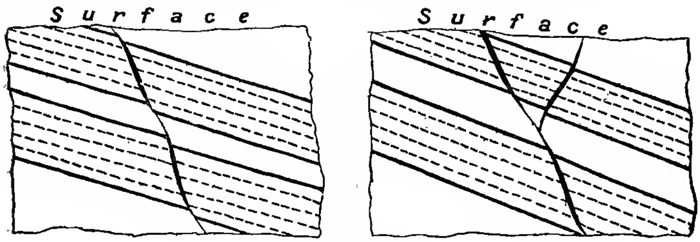


Fig. 12.—Section.

and the footwall of the secondary lode slid on the footwall of the main fissure, opening the flatter portions of the secondary fracture.

There are many districts in which the cause of upheaval is not apparent, no boss of granite reaching the surface, and yet the characters of the reefs point to an origin such as described; but there are many other localities, of which the Gulgong Goldfield, New South Wales, may be cited, where there have been other agents at work in the formation of reefs. At Gulgong the auriferous lodes are very closely related to dykes of diorite which penetrate the Silurian slates of the district, and the same may be said regarding many of the lodes of Western Australia. These dykes have clearly had something to do with the origin of the lodes, and have, moreover, determined to a large extent their auriferous character. They intersect the strata at various points and vary greatly in thickness; but where the strata are not penetrated by them the reefs do not appear to be auriferous, while the greater quantity of gold is in leaders traversing the diorites themselves.

In districts which are traversed by dykes, another series of considerations comes in. These dykes have been formed by the fracture of the strata from some cause or other, and the wedging

asunder of the beds by fused rock under great pressure. As this rock cooled, a number of cracks would be formed from shrinkage, which would not necessarily follow any special direction. At Gulgong the beds are traversed by a great number of flat-lying leaders, which, in many cases, die out entirely when they reach the junction of the intrusive rock with the sedimentary beds. It is more than probable that reefs which have no connection with these flat leaders, and were formed contemporaneously with the intrusion of the dykes, will yet be found traversing the adjoining slates.

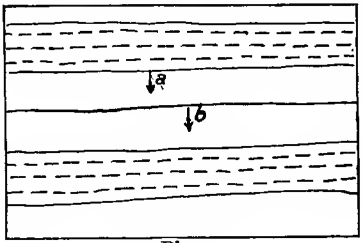
Lodes traverse strata which have been tilted at all angles, but are never continuous throughout their course in one particular bed. This leads us to the consideration of the distribution and extent of the rich parts of lodes.

Distribution of Ore in Lodes.—It is apparent that when the angle of underlay of a lode conforms more or less closely to the dip of the strata which it intersects, the character of the lode in depth will be more uniform than when it intersects a number of different belts of rock; because the angle of the line of fracture will be uniform over greater areas. Even, however, in cases of this sort, sufficient differences in the physical conditions of the rock will exist to make the fracture more or less irregular, and so there will be portions of the lode which are wider than others.

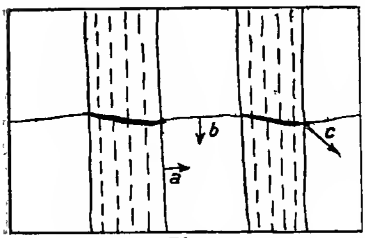
When, on the other hand, the strike of a lode corresponds over long distances with the strike of the strata, but the lode underlays at a steeper angle, and thus intersects a number of different bands in depth, constant changes in value will be found in sinking, but more or less uniformity horizontally; this constitutes the difference between lodes in which the ore occurs in shoots, and those in which it is chiefly found in flats or courses. When a lode which is underlaying at a steep angle also crosses the strike of flat-lying strata, it will intersect a number of different rocks, both along its course, and also in depth; and the ore will be distributed either in bunches, which have a very limited extension in every direction, or in very flat dipping shoots. As the course of the lode varies so as to more closely assimilate to the strike of the rocks, the horizontal extension of these bunches increases; while, as the strike of the lode approaches a direction at right angles to the bedding of the strata, the deposits occur in shoots, which dip steeper and steeper in the reefs as their direction more nearly approaches a right-angle to the bedding of the strata.

The following sketch plans are designed to illustrate the

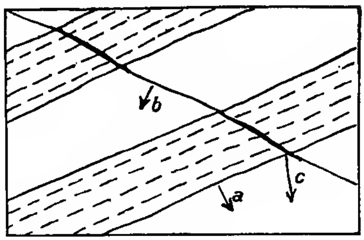
manner in which shoots of ore dip in lodes under different conditions, but the best idea can be gained by making a model and cutting sections through it in various directions.



Plan.



Plan.



Plan.

Fig. 13.—*a*, Dip of country; *b*, Underlay of lode; *c*, Dip of shoots.

In the foregoing illustrations, when the dip of the country increases, the shoots of ore more nearly approach the vertical; and when strata standing on end are intersected by a vertical reef at right angles to the course of the beds the shoots of ore are vertical, and practically occur as pipes or columns of ore.

It will be seen, then, that the character of the rock or country exerts a very great influence on the behaviour of lodes and on the distribution of the rich parts; this has been proved, beyond doubt, to be the case in every district which has been carefully studied. Every prospector is acquainted with the term "kindly ground," which is used to designate those belts of rock which are favourable for the occurrence of mineral deposits; but the characters of these belts vary greatly in different districts, and their local characters must be determined in each district which we may be called upon to examine.

As a general rule, those rocks which are moderately hard appear to be the most favourable for the occurrence of ore, because they possess sufficient coherence to remain open when

they have been fractured, and do not offer too great a resistance to fracture in the first instance. The softer rocks, such as shales, seldom carry valuable deposits; because the fissures formed are not likely to remain open as channels, but are quickly filled with fallen matter from the hanging wall.

The foregoing remarks give some idea of the manner in which the various lodes have been originally formed by fractures in the rocks, how these cracks have been opened by the action of gravity so as to form underground galleries through which water could circulate freely; and a study of the lodes themselves furnishes fresh confirmation of the facts that have been stated. It is found in many cases that the walls of lodes have been smoothed, polished, and striated by the sliding of one rough irregular surface on the other, and the direction of the striations shows the direction in which this sliding action took place. Where rocks are not sufficiently hard to preserve the striations or "slickensides," a thin clayey parting or "flucan," separating the lode from its walls, is frequently found, which, it can hardly be doubted, has been formed by the grinding of the rocks. The walls of lodes, for some little distance on either side, are also, in many instances, somewhat shattered by the movement which has taken place; and, at times, as for instance in the Alburnia mine in New Zealand, this change has been so marked as to give rise to the suppositions that the rock alongside the lode was different to that a short distance away; and that the bedding of the country corresponded with the underlay of the lodes themselves, instead of intersecting them at a flat angle as is really the case.

A study of reefs will also convince us that they have been deposited by the agency of water, for in many cases the mineral is arranged in a series of bands or zones parallel to either wall. In many cases also the walls have been altered by chemical means, sometimes for great distances from the lodes themselves; thus, in tin districts, the granite is often decomposed or kaolinised by the action of percolating water; while, in other localities, the walls are sometimes hardened by silicification of the rocks.

No lode has ever been formed by the intrusion of quartz in a fused condition. A very few moments' consideration will convince the practical prospector that this is the case, for quartz is one of the most infusible substances known; so infusible, in fact, that in many of the volcanic rocks, in which free quartz occurs, no doubt can exist that the crystals were formed in the internal laboratories of the earth and floated to the surface in the molten magma, a fact which is borne out by a microscopic examination of the rocks, when the lines of flow can be traced around the

crystals. Quartz, then, being of so infusible a nature, would, if it had been intruded in a molten condition, have been sufficiently hot to melt the more readily fusible rocks through which it passed, and any theory founded upon the supposition of filling from below by the agency of heat is necessarily wrong, as the walls of lodes never show any evidence of having been subjected to a heat sufficiently intense to fuse them.

Studying lodes, then, as simple fissures, the conclusion is arrived at that the average underlay of a lode does not in any way determine its ore-bearing properties; but that, even in the same district, lodes may be vertical or lie in an almost horizontal position and yet be equally productive; but the successive inclinations of the different parts of lodes are of the greatest importance in determining the distribution of the rich parts. As a general rule, the steeper parts of lodes are the richest, although this is not an invariable rule; the reverse being often the case when hanging wall leaders make junction with a main lode.

There are many other points, however, to be considered concerning the distribution of the rich parts of lodes. It will be remembered that lodes follow a sinuous course along the surface or along any level in a mine, and so the rich parts will be unequally distributed along a horizontal line. This irregular distribution also depends upon the different rocks through which the lode passes along its course, and since it is generally found that the richer parts are those in which the lode corresponds in direction most nearly to the line of elevation, this distribution of the rich parts in the upper levels of a mine will frequently serve as a guide by which to determine the "kindly country" of any particular district; and a geological examination of the district will afford data by which it may be inferred in what direction the shoots of ore dip in the lode itself.

Observations have hitherto been confined to a single fissure produced by a single upheaval or movement, but single fissures or lodes are of most unusual occurrence, and it is notorious that where they do occur they very seldom contain a sufficient quantity of valuable mineral to pay for extraction. As a rule, the force which has produced one vein has also produced a series of others parallel to it; and it is a noteworthy fact that where the behaviour of one of these has been determined, the behaviour of the others and the distribution of the rich parts can generally be predicted with some precision from a consideration of the conditions enumerated.

In the more known and better opened mining districts, such as Cornwall and Freiberg, it has been shown that several suc-

cessive series of lodes have been formed by tiltings of the strata from different points; and that the lodes following particular courses are generally characterised by special minerals; but the less known mineral districts have not yet been sufficiently studied to state these facts authoritatively.

These upheavals of the strata along different lines have not only opened a series of fresh reefs each time—the younger ones intersecting those which have been previously formed—but in not a few cases, the later movements have re-opened some of the old reefs in an irregular manner, and so some of the accessory deposits have been formed, which are frequently so difficult to account for, but which are met with in lodes from time to time, apparently defying all attempts to explain their origin or to predict their extent.

Rich deposits in lodes are also cut off abruptly at places by slides or faults, but the study of these and the means to be adopted for the recovery of lodes will form the matter for a subsequent chapter.

How Lodes were Filled.—A point has now been reached in the consideration of the subject at which it is necessary to allude to the manner in which lodes or reefs have been filled with their mineral contents. Before stating what is probably the true account of the filling of these cavities, it will be well to glance for a few moments at those theories which have been proposed, and which, for one reason or other, must be rejected as inadequate to account for observed phenomena.

In the early days of geological research there were two schools of geologists, one of which attributed everything possible to igneous origin, or the action of heat; while the other school sought the aid of water to explain most of the observed facts. It is needless to remark that these extreme views led to a very great number of absurd theories being propounded, both on one side and the other; but the mode of origin of reefs has remained a matter of dispute after many other points of difference have been settled.

It has been held by one school that reefs or lodes are of igneous origin, and have therefore been filled from below the crust of the earth; and, by the other, that they owe their origin to aqueous agencies, and have been filled from the surface; but neither of these views can be taken as correct in its entirety.

Of course, so long as these two theories were held by opposing parties, it was supposed that if a reef were filled from below, it would necessarily widen as it went down; whereas, if the filling

took place from the surface, the width of the reef would gradually diminish until it at last pinched out.

It will be seen from the explanation which has already been given concerning the origin of the fissures which have since been filled with different minerals, that all true fissure reefs must necessarily thin out and widen a great number of times between their outcrops and that point in depth at which the difficulties of working exceed the value of the mineral, for no true fissure vein has yet been proved to die out entirely in depth.

It is stated by many authors that another series of veins, known as "gash veins," does exist; but their occurrence is of a very doubtful nature. They are variously described as "lenticular cavities," "veins confined to one formation," &c., without regard to their mode of origin, and so include several classes of deposit which should be otherwise classified. Gash veins, if they do exist, may be regarded as lodes formed by the folding of strata after consolidation; those occupying the anticlines being necessarily wide towards the surface and narrower as they descend; whilst those occurring in synclines would widen in depth until the next underlying formation was reached, when they would cut out. It is possible that the saddle reefs of Victoria (which will be described in the chapter on Gold) might belong to this class of deposits, but by far the greater number of the so-called "gash veins" belong to one or other of the irregular deposits to be presently described. When a true lode appears to pinch out, it will inevitably widen again lower down; and when it is cut off by a slide, it may be found again heaved for a greater or less distance either to the right or left. What the prospector or miner has to decide is whether it is worth his while to spend the time and money necessary to again recover a lode that has been lost.

Having from time to time examined numbers of quartz reefs in different parts of the world, it may be safely affirmed that in no case that has come under my notice have the walls of lodes been altered by other means than decomposition or an infiltration of silica, which frequently hardens them; besides which, quartz, as already pointed out, is far less fusible than most of the rocks through which the reefs pass. A careful examination, moreover, shows that reefs have been opened by the sliding action previously described, the walls being frequently scratched and striated by this movement. When the walls are examined, no signs whatever of fusion having taken place can be seen, but many angular prominences yet remain. In many cases lodes are also found to have a banded structure in lines parallel to the

walls, the different bands sometimes containing different minerals, showing that the solutions which deposited these minerals varied from time to time.

A consideration of the foregoing phenomena leads to the conclusion that in every case lodes have been filled directly by crystallisation of minerals from solution, and that the constituents of these minerals have been dissolved from the rocks through which the subterranean water filtered. In some cases they may have been derived in the immediate vicinity of the lodes in which they are found; and, in others, they have come from some considerable distance, being only deposited when the waters have met with rocks of special composition or other conditions have been favourable.

In speaking of this subject it will be well to give some familiar instances of the solvent action of water under different conditions.

Limestone, for instance, is nearly insoluble in quite pure water; but when this water has previously dissolved a certain quantity of carbonic acid, which all rain water takes up in falling through the air, it is then capable of dissolving carbonate of lime. All water in limestone districts is "hard," or, in other words, contains carbonate of lime in solution; and the caves, which are always found in limestone, show the extent to which solution has gone on. Caves, however, not only afford proof that the limestone has been dissolved, but show also how it may again be deposited, the stalactites which hang from the roofs and the stalagmites on the floors having been thus formed. In many cases deposits of calcareous sinter occur on the surface, and some remarkable deposits are found in mines, to which allusion will be subsequently made. The action of carbonic acid is not, however, limited to the solution of carbonates, but has also the power of decomposing many minerals, such as the felspars, in doing which it dissolves the alkalies in the form of carbonate, and sets free silica in a soluble form. Quartz is also soluble in these solutions of alkaline carbonates.

The solvent action of water charged with carbonic acid is greatly increased when either the temperature or pressure is augmented, and as soon as the temperature is lowered or pressure decreased the substance held in solution is again deposited.

As a proof of the foregoing statement, reference need only be made to the hot-springs of the Rotomahana district, N.Z., where, before the Tarawera eruption which destroyed all the terraces which had been deposited by these springs, all the actions

specified were going on. The water came to the surface charged with carbonic acid, which was given off when it reached the surface, the pressure having been diminished, and the silica which had been dissolved from the rocks through which the water had passed was again deposited as sinter, forming the famous white and pink terraces. The silica held in suspension by the water was the cause of the bright pellucid blue colour so characteristic of these springs. The sinter consisted entirely of silica, while carbonic acid was evolved in large quantities at the geysers.

Sulphuretted hydrogen is not less important in the chemical laboratories of nature. As a gas it issues from springs in many districts, being readily recognised by its unpleasant smell like rotten eggs. This gas has properties which are relied upon for many reactions in analytical research. It precipitates some metals in acid, others in alkaline solutions; but most of the metals are dissolved in alkaline sulphides.

It is essential to remember that in all cases, whether water be charged with carbonic acid or sulphuretted hydrogen, the solvent action is greatly increased by pressure or heat; and that when the temperature is lowered or the pressure decreased deposition will ensue. This is the principal reason why minerals have been deposited in lodes, for it must be borne in mind that the water circulating in lodes cannot be under the same pressure as it was when in the pores of the rocks, and that as it rises towards the surface the temperature steadily decreases.

As an illustration, an extract may be quoted from Mr. G. F. Becker's report on the geology of the Comstock lode (*U.S. Geological Survey*, 1880-81):—

"Baron von Richthofen was of opinion that fluorine and chlorine had played a large part in the ore deposition on the Comstock, and this the writer is not disposed to deny; but on the other hand, it is plain that most of the phenomena are sufficiently accounted for on the supposition that the agents have been merely solutions of carbonic and hydrosulphuric acids. These reagents will attack the bisilicates and felspars. The result would be carbonates and sulphides of metals, earths and alkalies, and free quartz; but quartz and the sulphides of the metals are soluble in solutions of carbonates and sulphides of the earths and alkalies, and the essential constituents of the ore might, therefore, readily be conveyed to openings in the vein where they would have been deposited on relief of pressure and diminution of temperature."

"An advance boring on the 3,000 feet level of the *Yellow*

Jacket struck a powerful stream of water at 3,065 feet (in the west country) which was heavily charged with hydrogen sulphide and had a temperature of 170° F., and there is equal evidence of the presence of carbonic acid in the water of the lower levels. A spring on the 2,700 feet level of the *Yellow Jacket*, which showed a temperature of above 150° F., was found to be depositing a sinter largely composed of carbonates."

But it is not necessary to turn to America alone for illustrations of the filling of reefs, for any mining district which has been sufficiently studied will afford subject for reflection. In the Thames Goldfield, New Zealand, for instance, most of the phenomena alluded to are very clearly demonstrated. The country rock consists of numbers of stratified bands of submarine volcanic rocks, some of which are hard, green, and undecomposed; others consist of a softer white rock in which the felspars have suffered decomposition, and the rock itself is charged with numbers of small crystals of pyrites, especially near the reefs. The rock is also traversed by numerous small black veins, chiefly sulphide of iron and antimony, and it is in these decomposed rocks that the richest deposits of gold are found in the reefs. All miners who are acquainted with the Thames Goldfield will recognise the carbonic acid which has been alluded to in the heavy gas so prevalent below the 400 feet level, and which renders ventilation so difficult. The Big Pump affords an illustration of the quantity of carbonates held in solution under pressure and ready to be deposited when this pressure is removed; and the records of the Pumping Association show that a very heavy expense was incurred in cleaning the columns from the incrustation of carbonates, which, during the earlier days of the deep levels, formed with almost unprecedented rapidity.

It cannot be said that free sulphuretted hydrogen has been detected in this locality, but there is little doubt that it must have existed during the charging of the reefs.

It is a well-known fact in all mining districts that the junctions of lodes are generally the richest points, always supposing that the junction takes place in "kindly country;" the explanation of this is simple on the aqueous theory of filling of lodes.

Water traversing two different channels of necessity passes through different belts of country, and thus holds different substances in solution. As a case in point, suppose the water in one channel contains carbonates of lime and alkalies in solution, as well as silica derived from decomposition of felspars; and

that the other, charged with sulphuretted hydrogen, brought with it sulphide of antimony dissolved in sulphide of lime. The result of these two waters meeting would be that carbonate of lime would be formed, sulphuretted hydrogen set free, and sulphide of antimony deposited, as well as the silica which was formerly held in solution by the carbonic acid.

Numbers of such illustrations might be given, but it is not the object of this book to explain all phenomena which occur in lodes, but merely to direct the observations of prospectors into the right channels.

It is well known that in every district certain rocks are more "kindly" for one special mineral than for any other. Limestone, for instance, is very often the rock in which galena occurs; while gold is frequently closely related to diorite. In such cases the solution carrying the metals may have traversed various rocks flowing sometimes for great distances without meeting with conditions favourable for deposition, and only have met with these conditions when it reached that belt of country which we, in working the mine, designate "kindly ground," where, by an interchange of materials, by chemical action, in fact, deposition ensued, and shoots, bunches, or courses of ore were formed as the case might be.

This raises the very interesting question of the origin of gold and other minerals which have accumulated in lodes, and a very close relationship can hardly fail to be traced between the rocks encasing the lodes and the mineral deposits which occur in them. In connection with this a quotation may be permitted from Mr. F. S. Emmons's report on the mining industry of the Leadville district, Colorado, because it very well expresses the views it is desired to enunciate. He says:—"The earlier geologists devoted much speculation to the subject of the origin of metallic minerals in ore deposits, and arrayed themselves on the side respectively of the Neptunists or Plutonists, according as they believed them to have been brought to their present position by descending or ascending currents, whether gaseous or liquid. As pure theory has been gradually modified by the results of actual investigation, the upholders of the two opposing schools have come to concede in this, as in other questions of general bearing on geology, an element of truth even in the views of their opponents. Only extremists maintain that any series of geological phenomena admit of but one explanation, or are due to one universal immediate cause. It is generally agreed that subterranean waters, however deep seated their apparent source, came originally from the surface. It is, more-

over, proved that no rocks are absolutely impermeable to water, but as on the earth's surface, so within its solid crust, there is a constant circulation either through capillary pores, where it is not readily visible, or through the larger and more apparent channels formed by joints, cleavage planes, faults, dykes, and stratification lines, the direction taken by such waters varying with different local conditions. In the case, therefore, of ore deposits, which are derived from aqueous solutions circulating within the earth's crust, a class which is constantly augmented by scientific investigations, the question as to the immediate sources of the metals in solutions from which they were deposited, whether above or below the present position, is one which must be determined independently in each individual case, and to which no general answer can probably ever be given."

A few examples may be mentioned in illustration of the foregoing remarks. At Adelong, N. S. Wales, the reefs traverse a hard, undecomposed syenitic granite, and are undoubtedly true fissure reefs ; but the country rock from the surface to the lowest levels exhibits no appreciable change in its composition, the granite throughout being a hard, solid compact rock. The lodes themselves, however, are not completely filled with quartz, but are really softer channels of country largely composed of chlorite ; and all those parts which were not filled mechanically have since been charged with auriferous quartz by the circulating waters. In this case, the deposition of the gold and quartz was probably due to chemical changes induced in these softer channels, and not in any way to the decomposition of the solid granite itself. Grenfell, on the other hand, which is also in N. S. Wales, may be taken as a case in point where the rock has exerted a powerful influence on the mineral deposits. The rock in which the richest deposits of gold occurred in the Consols Reef was a dark-coloured porphyrite containing a dark-greenish mica, while in the lower levels, where the reef ceased to be payable, no mica was to be seen.

In this case, the presence of mica in the rock appears to point to the class of ground which possessed the necessary substances for precipitating gold, and shows how necessary it is to trace the extent and boundaries of different classes of rock.

Even more marked than this is the case of the Thames, where the shoots of gold can be traced through several different belts of rock with which other beds are interstratified, in which gold does not occur in payable quantities; and a section of the Alburnia Mine will illustrate this varying character very well,

those belts marked (*a*, Fig. 14) being the hard and unproductive country. It is often the case that the charging of reefs is attributed to what is known as solfataric action, the final stage of volcanic eruption when only steam and gases are emitted from the craters being called the solfatara stage. Where, as at the Thames, reefs are found traversing volcanic rocks, it is reasonable to suppose this to have been the case. In Mr. Becker's report on the Comstock lode, which has already been quoted, he shows, in a section from Mount Davidson through the upper

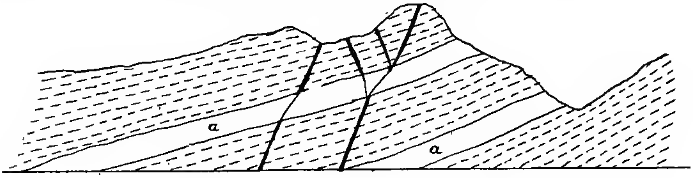


Fig. 14.—Section through Alburnia Mine.

end of the Sutro tunnel, several belts of country which have been decomposed by solfataric action, although it is worthy of notice that none of these bands approach the Comstock lode itself, which occurs at the junction of diorite and diabase at its outcrop, but intersects the diorite in depth.

In his report on the Mount Morgan gold deposits, Mr. R. L. Jack, Government Geologist for Queensland, attributes the occurrence of gold at that place to deposition from a hot spring. The country in the immediate vicinity appears to be traversed by dykes of rhyolite, and there are considerable deposits of siliceous sinter resembling in character the deposits of geysers. It is in association with these siliceous sinter deposits, as well as with brown and red hæmatite ores, which might justly be described as gossan, that the gold occurs. It is perfectly reasonable to believe that deposits of gold may be formed in this manner; indeed geysers and hot springs generally afford the best illustrations of many of the operations going on during the charging of reefs, and in isolated cases, such as Mount Morgan, substances of economic value may well be introduced; but it must be borne in mind that nearly all lodes which contain iron in any form, notably as iron pyrites, decompose near the surface to form a porous kind of hæmatite which is known to miners as "gossan," and that this gossan will sometimes extend for a depth of 100 feet to 150 feet from the surface before the true ore of the mine is met with.

It is very questionable whether the theory of deposition from

a hot spring is correct in the case of Mount Morgan, or whether the deposit is simply a lode which has opened to very large dimensions; later developments appear to point to the deposit being nothing else than a lode.

Gossans are due to the oxidation of ores of iron, and all substances in the lode which can be readily oxidised are so changed; where copper pyrites, for instance, is present it becomes changed to sulphate of copper, which is carried away in solution, leaving the gossan porous.

Noble metals, such as silver and gold, are rarely carried away in solution; but silver is frequently changed to the condition of chloride. All silver mines afford illustrations of how this action has gone on.

Bearing these points in mind, it will be evident that the character of a gossan will seldom afford any index of the true nature of the lode it covers. Generally speaking, lodes which have a good gossan on the surface are valuable in depth for one class of mineral or other; and a gossan which has a snuffy brown colour and great porosity may generally be looked upon as the best indication.

CHAPTER VII.

IRREGULAR DEPOSITS.

A GREAT number of the repositories in which minerals occur come under one or other of the divisions which are classed as irregular deposits, and, in some cases, they are of very great importance. Their irregularity, however, makes the extent of the ore even more uncertain than in lodes, such as have been described in the preceding chapter, and no rules can be enunciated which afford any guide as to their distribution. In certain cases huge deposits of ore are found which yield vast quantities of mineral; in others, a little ore occurs in bunches, always inducing further prospecting, but not always leading to deposits of sufficient extent and value to repay the cost of exploratory workings. These irregular deposits are, in fact, of the most speculative nature, and, while they at times result in the accumulation of large fortunes, they as often, or perhaps more frequently, only lead one to expend money on prospecting which is never repaid. It is unfortunately the case that no one, however experienced, can say with any certainty whether it is judicious to continue prospecting work on a particular deposit or

to abandon it, for, when the ore is poor and of small extent, a few feet driven may completely change the aspect of affairs and render a mine which had no encouraging features one which has a very considerable prospective value.

These irregular deposits may be subdivided as follows :—

1. Impregnations.
2. Reticulated veins.
3. Lenticular aggregations.
4. Irregular masses.
5. Contact deposits.
6. Cave deposits.

A description of the conditions of each of these will be given in this chapter, with some illustrations of their occurrence.

Impregnations.—It will be remembered that in the chapter on stratified deposits some instances have been given of the impregnation of beds by copper, lead, and gold, in which somewhat constant characters prevail over wide areas; but there are also rocks, frequently of igneous origin, which are impregnated with mineral in a most irregular manner, and which, at times, have been worked to considerable advantage. The cause of these impregnations is not always, or indeed often, easy to find, but frequently a joint in the rocks, looking like a wall of a lode (sometimes with a thin vein of quartz, calcite, or barytes) forms an indicator vein, and the impregnated rock lies on one or other side of this indicator, and occasionally the rock is impregnated with mineral on both sides of it. The distance to which this impregnation extends from the indicator is very various, and when cross cut may prove to be only a foot or two wide in places and at others to extend for a hundred feet or more.

Probably the best illustration that can be found of this class of deposit is in the mines of the Calico District, near Los Angeles, in Southern California, the rock of which district is andesite. The nature of the rock varies a good deal in different parts of the range of hills which rises from the edge of the Mohave Desert; but they are almost devoid of vegetation, and have weathered in large patches of iron red, pink, and green, thus affording a most curious patchwork appearance when seen from a distance, and one which would inevitably attract attention.

These rocks are traversed by veins, such as are described, and are impregnated with chloride of silver in a very irregular manner, but over a very wide extent. The ore is of a free milling character, and is worked by battery and pan amalgamation, the Boss continuous system being adopted. The deposits have been sufficiently rich at times to give rise to much litigation

between the respective companies which have been working them; but, taken on an average of the good and bad worked, they have yielded about 10 oz. of silver per ton of ore.

In some cases huge chambers, which can only be likened to caves of the largest type, have been excavated, the whole of the rock thus broken having been crushed and the silver extracted; while in other parts of the mines drives, many hundreds of feet in length, have failed to develop any ore that is of sufficient value to pay for extraction. It will be evident that mines of this class require the most constant care in sampling and assaying, and a rough system of testing whether the rock carries silver is practised in the mines, while regular assays are made day by day of all ore that shows sufficient indications to these rough tests.

Very closely related to these are the so-called fahlbands of Kongsberg, Snarum, and Skutterud in Norway, which are regarded as impregnations by von Cotta.

They are described by J. A. Phillips as "parallel belts of rock of considerable width and extent impregnated with sulphides of iron, copper, and zinc, and sometimes also with those of lead, cobalt, and silver." The fahlbands of Kongsberg are worked for silver, and are about 1,000 feet thick; but it is only in a few localities where they are sufficiently rich to pay for working. They are traversed by veins which are unremunerative in the gneiss and schists, but become highly argentiferous in passing through the fahlbands or grey beds, which exert the same influence on the veins traversing them as the ordinary "kindly country" does upon reefs or lodes in general, so that, in reality, these fahlbands hardly deserve to be considered as an independent class of deposits.

The cobalt deposits of Snarum and Skutterud also occur in fahlbands which are sometimes rich enough to pay for working, but these, unlike those of Kongsberg, are not traversed by mineral veins, and so would be more properly considered as impregnations.

In Western Australia there are decomposed rocks of considerable width which carry a little gold, but none have been found up to the present which will repay the cost of working. The occurrence of gold in this country in lodes in which the gangue is not pure quartz, but a ferruginous material containing, however, a large proportion of silica, appears to have led prospectors to think that every decomposed rock met with was of the same nature; and they have accordingly named these decomposed rocks "lode formation."

A considerable amount of work has been expended on these so-called "lode formations" without, however, demonstrating the fact that any of them are payable; while the lodes themselves, which these deposits are supposed to resemble, are the richest gold producers yet found in the colony.

Reticulated Veins (Stockworks).—In some districts certain belts of rock are traversed by a great number of small veins which intersect the country in all directions, forming a perfect network. Where these veins contain any mineral which is of economic value, the whole of the rock is crushed for the mineral which it contains. Where reticulated veins occur, the country rock itself is generally impregnated with the mineral as well; and, in some cases, the impregnation has no doubt been brought about by the infiltration of the mineral waters which charged the veins; while, in other cases, the rock was impregnated first, and the veins derived their mineral from the rock.

Deposits of this sort are called **Stockworks.** Tinstone is frequently found under these conditions both in Cornwall and Germany. Gold occurs under similar conditions at the Thames, New Zealand, as was seen when a portion of the spur on the Caledonian mine was crushed; and in many other mines a good deal of country rock is crushed when small veins traverse it.

Deposits of this class are of sufficient importance to merit some attention, and it should be borne in mind that when a number of small veins of mineral occur comparatively near together, which would not pay to work individually, it may be quite worth while to treat the deposit as a whole.

Lenticular Aggregations.—Certain minerals, notably ironstones and manganese, are found occurring in masses which very frequently coincide with the bedding of the rock, but which thin out in all directions. They have probably been deposited during the formation of the rocks themselves, and are exceedingly capricious as regards their extent and mode of occurrence; for when one deposit has been worked out no guarantee whatever exists that any more ore will be found in the district. These lenticular aggregations vary in size from small patches only a few inches across, up to masses of many thousands of tons.

Where minerals occur under these conditions, they have probably been precipitated from solution, in inland waters, by decomposing organic matter, such as wood or the leaves of trees, both of which are frequently found fossilised in beds of ironstone. At the present day there are deposits of iron ore being formed in some of the Norwegian lakes, and the peasants of the district earn a livelihood during the winter months by breaking the ice

and dredging for the accumulated iron ore, which is removed from time to time.

Irregular Masses include a great number of deposits, some of which are intimately associated with true fissure lodes, of which they appear to be offshoots; whilst others do not seem to be in any way connected with veins, although they have probably been formed in the same way as fissure lodes; others again are nothing more than shrinkage cracks produced during the cooling down of the eruptive rocks in which they occur.

It may frequently be noticed in working a lode that a small vein of ore or gangue goes off either from the hanging or footwall, and when this vein, which is sometimes less than a quarter of an inch thick, is followed, it opens out to a large mass of ore which is only connected with the lode by the small leader (Fig. 15).

Such deposits as these are of frequent occurrence in Cornwall, both in copper and tin mines, but notably in the former. They are known as **carbonas**, are, at times, of considerable size, and contain very rich deposits of ore. They would appear to be offshoots from the lodes, which have been filled by the waters which charged the lodes themselves; but chemical action has been set up in these cavities, and the precipitation of the mineral brought about.

Fig. 15.—Section.

Very closely related to these carbonas in point of origin are the so-called **tin floors** which were formerly of very frequent occurrence in Cornwall, but which of late years appear to have been worked out. These floors are intimately connected with the lodes, but are generally richer than the lodes themselves; indeed, in many cases where the lodes are absolutely barren, the floors have been very rich. They consist of flats of ore corresponding with certain beds of the strata, and die out at varying distances from the line of reef.

The following sketch will illustrate this class of deposit (Fig. 16).

In a few isolated instances, notably at the Park of Mines, near St. Columb, Cornwall, these floors have proved the principal ore-bearing deposits of the mine; but, instead of lying flat in

this particular instance, they are tilted at high angles, running like east and west lodes; for which they might be mistaken, except for the fact that they pinch out entirely at a short distance from the main north and south leaders, which are themselves only an inch or two thick.

It will be evident that deposits of this sort must have been filled by the waters which traversed the reefs; these floors, however, have not been formed as cracks in the rock, but are planes along which segregation has taken place from the country under the influence of the mineralised water in the reef.

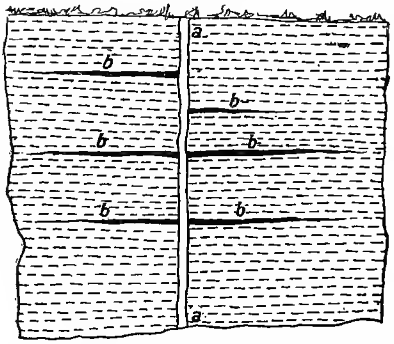


Fig. 16.—Section.—*a*, Lode; *b*, Floors.

A study of the rocks in which these floors occur will afford evidence of their origin and the case of the Park of Mines, quoted above, is most conclusive. The rock at this mine is clayslate or "killas," and wherever the tin floors are found the rock has been decomposed for some distance from the tinstone, and, the iron in the "killas" becoming peroxidised, the rock is coloured bright red. This is so marked a feature that when, in driving along the north and south leader, the country begins to assume a reddish tinge, it is a certain indication that tinstone will shortly be met with; and in working the tin floors any change in the colour of the rock is a sure sign that the end of the ore deposit is being reached.

Flats of ore are of quite a different character. They are found corresponding with the planes of bedding in sedimentary rocks, and closely resemble stratified rocks, for which they might readily be mistaken. When these flats, however, are driven on they are found not to thin out in the way lenticular deposits do, but to terminate in a vein which traverses the next belt of country, and will, if followed, generally lead to another flat in a different bed.

The character of these deposits will be best illustrated by a sketch (Fig. 17). They would appear to owe their origin to similar causes to those which have formed true fissure reefs, the lines of least resistance, however, having followed the bedding planes at places. It is not improbable that the cavities thus

produced have been enlarged by chemical action, especially where these flats occur in limestone country.

The last class of deposits which comes under this group is known as **segregated veins.** These are confined chiefly to igneous and metamorphic rocks, which, in cooling or drying, have shrunk and formed cavities in their interior; these are at times lenticular in shape, at others nearly spherical, and yet again of very irregular form. They must be clearly separated from true fissure veins or lodes; firstly, because they are limited in extent, and, secondly, because it is by no means necessary for any movement to have taken place in order to open these cavities. There is also considerable difference between the way in which true lodes and these veins of segregation have been filled, which may best be illustrated by a description of some of the segregated veins of pegmatite which occur in granite.

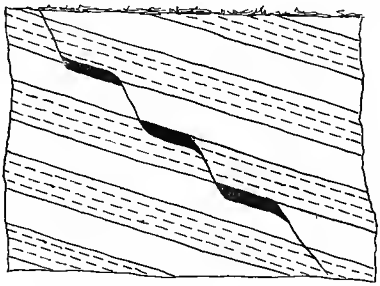


Fig. 17.—Section.

These veins of pegmatite have the same composition as granite itself, but consist of much larger crystals, large sheets of mica frequently occurring as well as crystals of felspar of considerable size. These veins are not divided from the enclosing rock by distinct walls, but the crystals of the pegmatite vein frequently penetrate into the enclosing granite. The large crystals have been slowly formed by a recrystallisation of the constituents of the granite after the crack was formed, and a vein of pegmatite affords a good illustration of the way in which metallic minerals are segregated in these veins. It will be seen at once that in segregated veins only such minerals can be looked for as are present in the enclosing rock in greater or less quantity; whereas the minerals in fissure lodes may have been carried in solution for some distance. Very valuable information concerning the nature of the rock may frequently be derived from a study of these veins of segregation.

Contact Deposits consist of accumulations of mineral along lines of junction of two dissimilar rocks which are sometimes of very different age. In the greater number of cases contact deposits are found at the junction of eruptive and sedimentary

rocks, or between two series of eruptive rocks; while they also, at times, occur at the junction of limestone with other stratified deposits. Where eruptive rocks form one of the walls of the deposit, the intruding rock appears to have left cavities which have subsequently been filled with mineral; and, from the nature of their occurrence, it will be evident the deposits of ore must necessarily be of a very irregular character.

The cavities do not always occur absolutely at the junction of the two rocks, but may be found at a short distance away on either side of the line of junction; hence, in prospecting, while it is necessary to drive along the line of junction, short cross-cuts at intervals, on either side, are necessary to prove the existence of ore. The remarkable deposits of copper at Monte Catini in Tuscany belong to this class, and are chiefly associated with serpentine; and the celebrated Comstock lode was at one time considered to be a contact deposit; but in its lower levels it passes from one rock to another, so that it is now regarded as a true fissure vein. It is difficult, however, to understand how a lode from 100 to 200 feet in width could have been opened by the sliding of the hanging wall on the foot wall, unless by successive movements which opened the fissure from time to time.

An instance of the occurrence of copper ore at the junction of limestone and slate may be mentioned in the Merces mine in Portugal, where the ore is very rich, containing as much as 30 per cent. of copper and up to 3 ozs. of gold per ton; but the deposits have hitherto been very irregular and send off shoots into the limestone in the upper levels of the mine, and also calcareous veins carrying ore which intersect the slate.

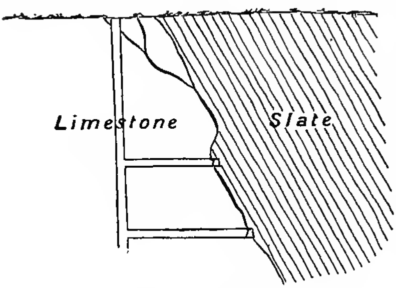


Fig. 18.—Section.

The adjoining sketch section of this deposit will be of interest as showing how one class of deposit may merge into another (Fig. 18).

The filling of these cavities has in some cases taken place by a segregation of the mineral from one or other of the enclosing rocks; but in other localities the waters carrying the mineral in solution may have come from a considerable distance.

Numerous other instances of contact deposits might be cited, but it is unnecessary to give further illustrations.

Cave Deposits include all those deposits of mineral which are found in irregular-shaped masses in limestone, and they might be subdivided into chambers or pockets, flats or sheets, and pipe veins. An examination of any of the numerous caves, which occur wherever beds of limestone are found, will give some idea both of the irregularity of the deposits and the way in which the cavities have been formed.

All caves in limestone have been dissolved out by the action of water charged with carbonic acid, but the direction of the drainage of this water is originally determined by the fracture of the rocks, and, in many cases, the size of the cavities has been greatly increased by mechanical degradation when, as is often the case, rivers have been diverted and flow through these caves for a greater or less distance. There is a river which, flowing into a limestone cave at Trieste, again comes to the surface 10 miles away, having followed a subterranean course for that distance. The Takaka River, in New Zealand, is dry during the summer months for some miles of its course, the water of its upper reaches once more coming to the surface a few miles from the sea in the remarkable Waikaremumu (bubbling water) springs, whence it issues in great volume.

Caves are extremely irregular in form; sometimes they open out into huge chambers, several of which are frequently joined one to the other by small passages through which a man can hardly crawl. It is not unusual to find holes in the floor down which streams of water pour to unfathomable depths; while in others, if a stone be dropped it can be heard striking first on one side and then the other until at last the sound is lost.

These different cavities afford illustrations of the various mineral deposits in limestone, and show how extremely irregular they are likely to be. The chambers in which stalactites and stalagmites are generally found correspond to the so-called chamber deposits and pockets, and the holes just described afford a good illustration of the so-called pipe veins of galena, which have been largely worked in the carboniferous limestone of Derbyshire.

Lead ores are of most frequent occurrence in these cave deposits; but at Alston Moor, in Cumberland, hæmatite and calamine have also been found under similar conditions, and calamine is worked at Laurium, in Greece, in cave deposits in limestone. Gold and silver, associated with metallic sulphides have also been found in cave deposits in limestone at the Eureka,

Consols, and Richmond Mines, Nevada, and at the Flagstaff Kessler Cave in Utah. Carbonate of manganese has also been worked under similar conditions at Las Cabesses, in France, this being an almost unique instance of the occurrence of this mineral in workable quantities.

Some authors include these cave deposits under the term of "gash veins"; but the classification is evidently incorrect, because the first cause of the formation of cave deposits may be due to movement just as well as fracture, and in some cases cave deposits change to true fissure lodes in depths when the limestone beds are passed through.

The foregoing brief description of irregular deposits will be sufficient to indicate the general conditions under which minerals of commercial value may occur other than those which prevail in true lodes; but it must be borne in mind that, while the divisions are made, no hard and fast line should be drawn between them, for contact deposits or cave deposits may pass into true fissure veins, and many of the other deposits are frequently associated with lodes of which they are offshoots, thus the description given can only be taken as a guide for the assistance of prospectors in following up what surface indications they may find.

CHAPTER VIII.

DYNAMICS OF LODES.

Referring to Chapter VI., it will be found that lodes traverse the country in many different directions, and that, in districts which have been carefully studied, those lodes which follow different courses are, as a rule, characterised by special minerals.

It is seldom the case, where more than one system of lodes occur in a district, that the same upheaval which produced one of these systems was instrumental in fracturing the rock in other directions. The lodes are generally described as **right running lodes, cross courses,** and **caunter lodes**; the first term being applied to the main lodes of the district, whatever their direction; while the cross courses are those which run nearly at right angles to them, and the caunter lodes in any other direction.

Faulting of Lodes.—It will be evident, where each of these systems have been caused by upheavals along different lines,

that these upheavals must have taken place at successive times, and the systems of reefs will be of different ages; also that the older systems will be dislocated and, perhaps, displaced by those of later date.

This being the case, in order to follow the rich parts of the lodes with the least amount of dead work, a study must be made of the geological structure of the district in order to find which is the oldest system of lodes and how they have been dislocated, so that the displacements which have taken place in those lodes which have been intersected by the younger ones may be investigated.

In order to clearly explain these displacements it will be well to revert for a moment to the formation of lodes. It is known that, in the majority of cases, these are formed by fractures of the strata which are more or less nearly parallel to the lines along which elevation has taken place. Under these circumstances, where several systems of lodes occur in a district, they must have been formed by successive elevations of the country along different lines, and the later formed cracks or fissures would intersect those which had been already made. If, then, a district has been subjected to many such movements, the reefs occurring may present a complete network, and the work of tracing them may be somewhat complex.

It may be accepted, as a rule, that true fissure lodes are never opened so as to form underground drainage channels without a certain amount of movement taking place; without, in fact, the occurrence of a fault with a greater or less throw—in other words, the formation of a lode necessarily displaces the strata through which the lode passes.

Bearing this in mind, it is evident that when rocks are traversed by a fissure lode the beds on one side of the lode will stand at a higher level than those on the other side; and, necessarily, if the country be again faulted along lines which are not parallel to the former lodes, that, in addition to the bed rock being displaced, the reefs which were already formed will be subject to the same movements; hence we may always be certain that any lode which intersects or displaces another is the younger of the two.

Relative Age of Faulting.—Having carefully studied these peculiarities of the lodes (and the information required can generally be obtained at an early period in the history of a mining district), it is possible to trace with accuracy the order of events in the formation of the lodes, and to decide, for instance, whether the E.W. lodes displace those striking N.S.,

or are themselves displaced; and whether the north-east or north-west lodes are the oldest or youngest on the field, intersecting one system and being cut themselves by the other. Some opinion can thus be formed as to whether the lodes being worked are likely to be faulted, or will run as master lodes through the district. These main considerations being settled for any particular locality, a study must next be made of the results which accrue in the various lodes, and an endeavour made to lay down laws which will serve as a guide in searching for those lodes which have been cut off by slides or younger intersecting lodes. In order to clearly understand the matter, it will be better to illustrate the various cases with a diagram (Fig. 19):—

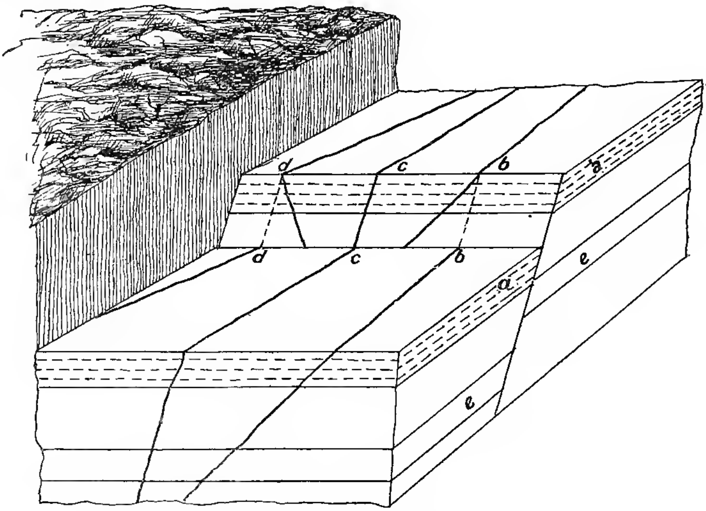


Fig. 19.—Section.

In the foregoing section beds (*a*) and (*e*) (which are shown as approximately horizontal, or with only a slight dip) are traversed by reefs (*b*), (*c*), (*d*) which strike and underlay in different directions; these have been dislocated by a fault. Several most important features are illustrated by this section.

In the *first* place, it will be seen that where a fault traverses horizontally-bedded strata, the beds on the hanging wall side of the fault occupy a lower horizon than those on the footwall side.

Secondly, that the movement takes place in the direction of the dip of the fault.

Thirdly, when reefs traversing the strata are dislocated by a fault it is seldom the case that the dislocated lode dips in such a direction that, being faulted, will make no apparent difference between the course of the reef on the hanging and footwall sides of the fault. In the majority of cases the dislocated lode will appear to have been subjected to a side movement, as well as an up and down one, this apparent lateral movement being called a "heave" by miners. The diagram will illustrate sufficiently how it is that the reefs appear to be heaved, when they have in reality been only faulted; but it is necessary to point out that these apparent heaves are sometimes to the right hand and sometimes to the left, and also may be either in the direction of the greater or lesser angle formed by the intersection of the reef and fault. When a slide is intersected in driving along a lode, some laws will be necessary to determine—*firstly*, in which direction to search for the lode which has been cut off; and *secondly*, the probable distance that will have to be driven in order to intersect the lost lode. The first of these questions can be settled in the majority of cases by a rule which will be given by and by; the latter involves a very accurate knowledge of the geology of the district.

In arriving at a conclusion in the first case, when it is simply desired to know the direction in which to drive for the recovery of the lode, it must be clearly borne in mind that, as already pointed out several times, a slide, cross-course, or lode which intersects the reef that is being worked is, mechanically, nothing more than a fault. This cross-course may be an ore-bearing lode on the one hand, or it may be nothing more than a fissure in the rocks filled with clay, or sometimes it may even be an open watercourse. In any case, however, it is a fault, and in the greater number of cases the hanging wall portion of the country will have slid downwards upon the footwall portion. As already shown, in describing the section (p. 116), where a fault intersects rearing seams of coal, or reefs standing at a high angle, there will be an apparent lateral heave in one direction or the other.

Law regulating Direction of Heaves.—In the early days of mining these heaves were noticed, and the miners of 300 years ago observed that in the majority of instances where a lode was intersected by a cross-course the heave took place in the direction of the greater angle. In other words, if a drive was being made along the course of a lode, and a fault was inter-

sected, as in the following sketch plan, the lode would generally be heaved from a to a', or in the direction of the greater angle, x. It was further known that when it could once be determined in which direction the lodes of a district were heaved by any series of cross-courses, the law might generally be applied to the district in question. Thus, for instance, if it was found that the lodes were generally heaved to the right hand when they met a cross-course, it would be said that the district was one of right-hand heaves. Both of these rules are applicable in a greater or less degree, but they have been very thoroughly tested in Cornwall by Mr. Henwood, who has catalogued all the peculiarities of the more important lodes there.

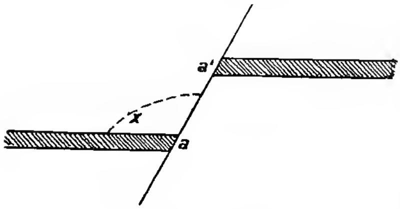


Fig. 20.—Plan.

He states that out of 233 intersections of lodes examined, 53, or 22·7 per cent., were not heaved at all; while of the remainder, 150 were heaved in the direction of the greater angle, and 30 in the direction of the lesser angle, 119 being right-hand, and 60 left-hand heaves.

Of those lodes, then, which are heaved by intersecting cross-courses in Cornwall, the following percentages represent their respective directions:—

Heaved to the right hand,	66·1
,, left ,,	33·9
	100·0
Heaved in direction of greater angle,	83·3
,, ,, lesser ,,	16·7
	100·0

It is perfectly evident, then, that these percentages do not afford a satisfactory rule, even in Cornwall where they have been studied, since they only give an approximate notion of the direction in which the heave has taken place. In order to give a definite law for the recovery of lost lodes a rule was devised by Schmidt and Zimmerman, with the result that when applied to the Cornish lodes it was found to be correct in forty-nine cases out of fifty.

Schmidt's Law.—To apply Schmidt's law it is necessary to know accurately what is the strike and underlay of both the lode and cross-course; this can best be determined by actual survey in the mine where two levels have been opened; but where this is not the case the average strike of the reef and cross-course can only be taken in the level being driven, the underlay being determined by the plumb bob or clinometer.

Having, however, arrived, by the best means available, at the true strike and underlay of the reef and cross-course, it is next necessary to show these on a plan, the object being to delineate the points of intersection of the lode and cross-course at two different levels in the mine, and thus obtain the line of intersection of these two between the different levels. It will be better here again to illustrate the method with a diagram.

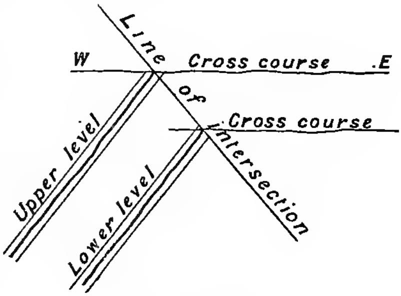


Fig. 21.—Plan.

It will be seen from this diagram (Fig. 21) that by means of a survey the exact position of the intersection of the lode and cross-course can be determined at the different levels, and the line of intersection can thus be delineated on plan as shown. Where, however, the mine has not been opened out on successive levels the course of the lode and cross-course can only be taken at the one level to which access can be had.

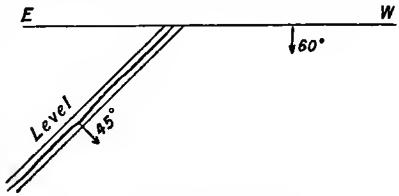


Fig. 22.—Plan.

By means, however, of a clinometer and compass the angle and direction of underlay, both of the reef and cross-course, can be taken. In the illustration (Fig. 22) let it be supposed that the lode is underlaying in the direction indicated by the arrow at an angle of 45° from the horizontal, and the cross-course at an angle of 60°.

If, then, any vertical distance is assumed as between the lines *a b*, *c d* (Fig. 23), and the underlay of the reef and cross-course be drawn as represented by *e g*, *h l*, the line of intersection can

be arrived at as follows:—Drop *e f* and *h k* perpendicular to *c d*, cutting off the distances *f g* and *k l*. Then on the plan (Fig. 24) erect a perpendicular to the lode and another to the cross-course, and cut off the distance *f g* from the former, and *kl* from the latter. Draw lines parallel to the lode and cross-course respectively through the points *g* and *l*; these will intersect at *x*, and *x y* will be the line of intersection.

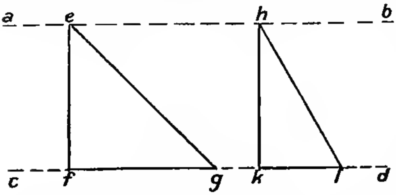


Fig. 23.—Section.

Schmidt's law may be defined as follows:—If a lode is intersected by a cross-course or fault, and the lode is heaved either to the right or left, then, in order to find in which direction this heave has taken place, it is necessary to know the direction of the line of intersection of the two. This being determined, the course of the lode and cross-course having been shown on a plan, and the line of intersection also indicated, the determination in which direction the heave has taken place is simple. A perpendicular is erected to the cross-course at the point *a* (Fig. 25) on the side on which the lode is lost, as in the following diagram.

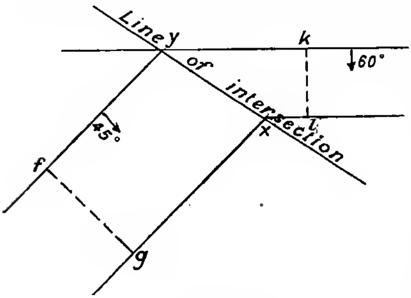


Fig. 24.—Plan.

The line of intersection is produced to *b*, and then on whichever side of the line *a b*, the perpendicular *a c* falls is the direction in which to search for the lost lode. In the case given, *a d* would be the direction in which to drive.

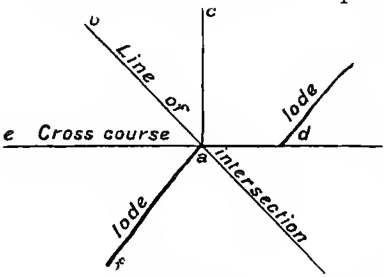
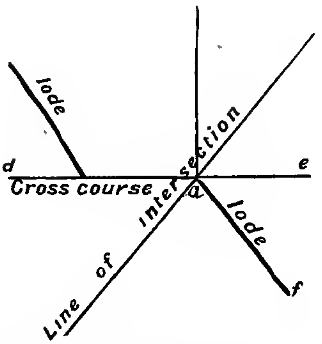


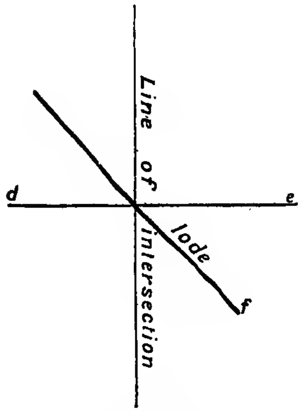
Fig. 25.—Plan.

The following diagrams show that in some cases the lode will not be heaved at all by the cross-course, while in others it may be in the direction of the greater angle *f a d*; and in others in the direction of the lesser angle *f a e*.

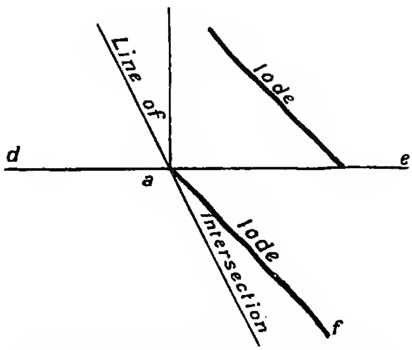
The distance to be driven in either case can only be found when the amount of vertical displacement of the fault is known, and this cannot always be determined. Where accurate plans



Lode heaved in direction of greater angle.



Lode not heaved.



Lode heaved in direction of lesser angle.

Fig. 26.—Plan.

and sections of the geological structure of the country traversed by the fault are available, the exact position of the beds on either side of the fault may be recognised; and, having the

amount of vertical throw, the heave can easily be determined, since by setting out the line of intersection in elevation instead of plan, the ratio which exists between the vertical displacement and the heave can readily be arrived at.

Exceptions to Schmidt's Law.—There are a few cases in which Schmidt's law does not apply, but these are chiefly where subsequent movements have taken place, tilting the fault from its original plane to one dipping in the opposite direction. It will be readily seen that in some cases the movements are very complicated and require most careful study before they can be properly understood.

The following plan will explain what a complicated network might be produced by the successive action of two faults with their corresponding heaves on a single lode :—

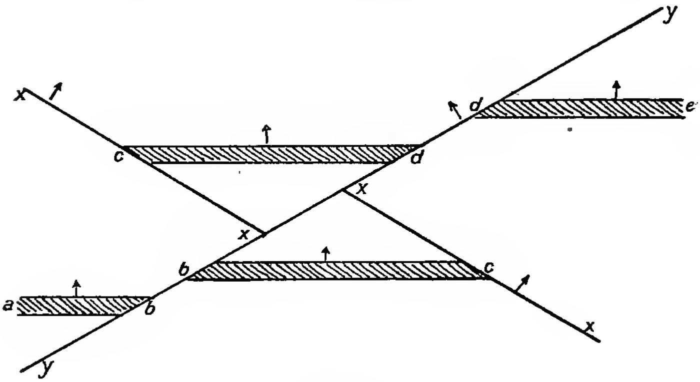


Fig. 27.—Plan.

The lode *a b c d e* was originally one continuous fissure, and was first of all heaved by the fault *x* in the direction of the lesser angle; subsequently, the country was dislocated by the fault *y* which heaved both the lode and the original cross-course in the direction of the greater angle, thus giving rise to the somewhat complicated structure apparent in the plan.

A study of this plan illustrates very well the comparative dates of the different dislocations. It will be evident that in the first case the country was broken by elevation parallel to the once continuous line *a b c d e*, and, the fissure being opened in the manner previously described, the channel was filled with ore before the second movement took place. This second move-

ment was an elevation parallel to the line x, and it will be evident, from the way in which the lode is heaved by it, that the lode and fault x are underlaying in the direction indicated by the arrows on the plan. The underlay of the fault y must also be as indicated, and the elevation parallel to the line y must have been the last structural movement which had taken place. Other cases may occur in which a lode is intersected by a cross-course which strikes in the same direction as the lode, but underlays in the opposite direction, as below (Fig. 28); in cases of this sort there will, of course, be no heave apparent, but the same lode may be brought to the surface several times by parallel faults.

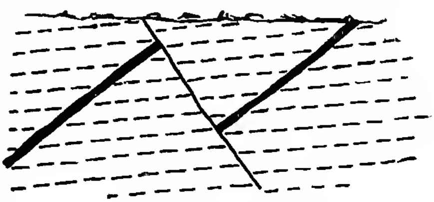


Fig. 28.—Section.

Some districts are traversed by a great number of faults of this sort, and taking Grenfell, New South Wales, as an illustration, the reefs have been faulted time after time, so that at present the quartz appears to occur in a succession of isolated blocks which are found following a zigzag line through the country from the surface downwards, the blocks seldom having a greater extent than about 200 feet.

The lodes in this district occur in a rock which is called porphyrite, consisting of felspar crystals in a felsitic base; near the surface, and for some hundreds of feet below it, the rock has been decomposed and changed from its original blue colour to a sort of dirty brown. This rock, although hard to work in the mines (requiring the use of explosives), crumbles away rapidly when exposed to the action of the atmosphere; it traverses the country in a north and south direction, the beds on either side of it to the east and west being slates. In these slates several reefs have been found which run parallel to the main line of upheaval; but in no case have they proved to contain a sufficient quantity of gold to pay for extraction. In the belt of porphyrite, however, some very rich reefs have been found; but instead of running north and south, as in the slates, they traverse the porphyrite obliquely, coursing north-east and south-west and underlay to the north-west at angles varying from 56° to 65°.

As already stated, these reefs have been subjected to numerous heaves, and these have generally thrown the reef in the direction of the footwall; so that a vertical section of one of the mines would be much as shown in the adjoining sketch (Fig. 29).

In all cases where the reefs have been set back in this manner the slides which have dislocated them traverse the country at very flat angles, and the movement, instead of being a sliding or settling down of that part of the country, which is on the hanging wall side of the reef, is represented by the reverse faults which have been previously described. Hence Schmidt's law would not be applicable in driving for the recovery of the lost lodes.

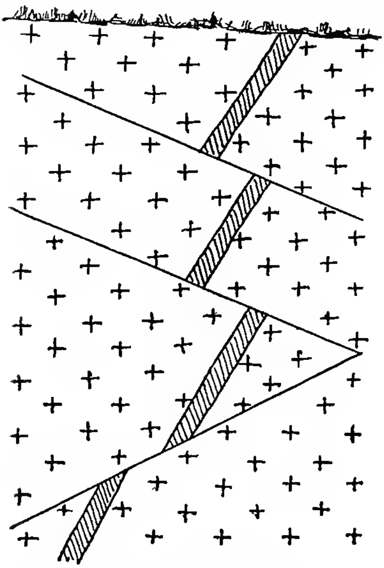


Fig. 29.—Section.

There has, however, been one exception proved to this rule in the Homeward Bound Claims, where highly payable stone was traced to a depth of 300 feet from the surface. Several floors, such as described, were met with which heaved the reef into the footwall, sometimes for as great a distance as 25 feet, but at the 300 feet level the reef jumped for a distance of 9 feet into the hanging wall, and it is worthy of note that the slide which dislocated the reef at this point traversed the country at a steeper angle and, on its underlay, met the underlay of the reef; so that normal conditions supervened, and the movement which took place was a downward one on the hanging wall side of the slide.

Other instances might, of course, be quoted in which Schmidt's law is not applicable for the recovery of lost lodes, but in by far the greater majority of cases the rule is applicable; the exceptions are only given with the view of explaining why in certain cases it will lead to incorrect conclusions.

CHAPTER IX.

ALLUVIAL DEPOSITS.

HAVING alluded to all the different conditions under which minerals occur, either as reefs or stratified deposits, it is now proposed to devote a chapter to a description of those repositories of minerals known as **alluvial deposits.** This subject is of the more importance because, although they are of a less permanent character than reefs, the greater quantity of both tin and gold which has, up to the present time, been won, has been derived from deposits of this sort; and large areas still exist in which a judicious application of capital on comparatively poor ground will be remunerative. It should be mentioned here that the only minerals of importance which are found in alluvial deposits are gold, the other precious metals, as well as tinstone and the gems which, from their hardness, and their power of resisting chemical change, are preserved in their original state, even when submitted for long periods to the action of the weather.

Source of Materials.—It will be evident to all that alluvial deposits have been derived, in the first instance, either from reefs or irregular deposits, such as described, or from rocks which are impregnated with mineral; and that, in the majority of cases, the tin and gold found in these alluvial deposits have also been derived directly from reefs, although it is probable that the larger nuggets of gold were deposited by chemical or electrical action at the places where they are found.

Age of Parent Reefs.—Although at one time these alluvial deposits formed part of parent reefs, and have, by the denuding and transporting action of water, been broken down and rounded, they were in some cases detached from the reefs at a very early period in the history of the earth, and have since been subjected to the action of water flowing in many different directions; hence, the discovery of payable alluvial gold may not afford the means of tracing directly the reefs from which this gold was derived.

In order to render this quite clear, it is necessary once more to refer to the rocks in which the reefs occur, and the periods

during which the fissures were formed that are now filled with mineral deposits.

A special history necessarily appertains to each individual district, and it is manifestly impossible to deal in these pages with many instances; but it will be of interest to mention a few as illustrating the class of investigation that may be adopted by the prospector who will take sufficient trouble to study the reasons for the various facts that he observes.

Australian Reefs.—In Victoria the reefs chiefly occur in Upper Cambrian and Lower Silurian rocks; while in New South Wales they traverse the beds of the Upper Silurian and Devonian systems. During the Devonian period, or at its close, great upheavals took place, granite in many places was brought to the surface and the enclosing rocks were fractured along a number of lines, the direction of which depended upon the lines of upheaval of these granites. The fissures formed were charged with mineral, and from that time the formation of alluvial deposits commenced, the rocks themselves being worn away by the action of running water, and the minerals broken from the reefs concentrated in the river channels of that day. There can be no doubt that such was the case, because at the base of the coal measures of New South Wales there are beds of conglomerate in which water-worn gold occurs, and sometimes, as at Tallawong, there is sufficient gold present to make these conglomerates worth working.

Of course, the gold in these conglomerates must have been derived from reefs which existed before the Carboniferous formation (now occupying such a large area in New South Wales) had been deposited; but, at the same time, there are many reefs in the country which are of much later origin. The Silurian rocks, for instance, are traversed by dykes of diorite, some of which are on such a massive scale as almost to merit the term of bosses, and it has been pointed out by the late Mr. Wilkinson that many of these dykes are very closely associated with the occurrence of gold.

Dykes of this rock penetrate not only the coal measures, but also the younger Hawkesbury sandstone, so that it is a difficult point to determine the period of their intrusion or even to say whether they are due to one or a series of eruptions. Be that as it may, however, it is perfectly certain that at some places the reefs are due to the intrusion of rocks of this class, and a study of the alluvial deposits in these districts gives unmistakable evidence of the fact that the gold was derived direct from the parent reef.

A visit to some of these localities, or even an inspection of a map on which the reefs and gold leads are delineated, is convincing of the fact that the alluvial deposits have been derived directly from the reefs. The streams in which the alluvial deposits occur cross the belts of country in which the reefs are found, and it is only those parts of the streams which now lie below the line of reef that payable gold has been obtained. This distribution of the gold not only points to the fact that it has been derived directly from the reefs, but also shows conclusively that the drainage system of the country has not been changed since the alluvial deposits began to be formed.

But this is not always the case; for, in other localities, very great changes have ensued since the earliest deposition of the gold-bearing gravels. For instance, it has been pointed out by Mr. Wilkinson that at Biragambil, New South Wales, there is a gully in which payable alluvial deposits occurred that have since been worked out, the gold of which could only have been derived from the auriferous conglomerates of the coal measures; these conglomerates were denuded and their gold concentrated by a process of natural sluicing. The proof that this is the case is to be found in the fact that above a certain point in the gully, a point at which the coal measures cease, and Silurian slates are met with, no gold has yet been found; nor are the conditions of the slates such as are favourable for the occurrence of reefs.

Deep Leads.—There are also some other and most important alluvial drifts in the Gulgong district, which have not been deposited by existing streams, these drifts being known as the deep leads; they are found at considerable depths below the surface of the ground, and are frequently buried beneath as much as 100 feet of basalt. Similar conditions prevail in Victoria and New England.

These gravels were deposited by streams which, flowing during Miocene and older Pliocene times, had a somewhat different course from those which flow at the present day, and their course was suddenly arrested during the middle Pliocene period by streams of molten rock, which, flowing from fissures opened in the surface of the ground, poured down some of the watercourses and dammed back the water in others, up which they flowed until they found their level. The magnitude of this eruption can be appreciated when it is remembered that in the New England district around Armidale the granites and other rocks (which had been, since the Devonian period, subjected to the eroding action of water, and had been cut by it

into a number of gullies and gorges) were once more levelled off and converted into a table land, all the irregularities being filled up by this molten rock.

It has been suggested by Mr. Norman Taylor that it was in some way due to the effect of this basaltic eruption that the occurrence of diamond in the older drifts of Gulgong can be traced. There are many interesting places in this neighbourhood in which there is much difficulty in accounting for the manner in which the gold drifts were brought to their present position. Amongst others the Canadian and Whitehorse claims may be mentioned, in both of which the auriferous gravels now lie at a much lower level than any of the surrounding country, being, in fact, deposited in a depression. It is true that both these deposits, which adjoin one another, are resting on limestone and, indeed, are found in cavities in the limestone itself; hence, one is led to the conclusion that the river which deposited this gold very probably had an underground course for some distance, in which case a lead of gold may yet be traced through caves of limestone which mark the former course of the river.

These deep leads have since, at times, been again cut through by streams, which have in places even cut gorges through the basalt, and the earlier deposits have been once more concentrated by the action of running water.

New Zealand Reefs and Deposits.—In New Zealand the conditions have been very different to those which prevailed on the Australian Continent. It is true that auriferous reefs are found traversing Lower Silurian beds, as in Victoria, and Upper Silurian beds, as in New South Wales; but they also intersect both Upper Devonian and Lower Carboniferous rocks, which in this country consist chiefly of slates, sandstones, and breccias. The lower Secondary rocks which overlie these beds are not traversed by reefs, so that probably the date of the formation of the reefs was anterior to the deposition of these beds. There is, however, no absolute proof that this is the case, for the earliest known alluvial deposits in New Zealand are those known as the cement workings of Cement Town, near Reefton, which are of Cretaceous age; they belong to the coal measures of the colony, which, as already pointed out, are Cretaceous.

All that is known for certain of the period of formation of the reefs is that they were formed after the close of the Carboniferous period, and before the commencement of the Cretaceous period. There is ample evidence in support of this, for alluvial gold, more or less rich, is somewhat widely distributed on the west

coast of the South Island in rocks of Cretaceous age; while some very rich deposits of recent date are due to a natural concentration of these gravels.

As an illustration, the Mangles River, a branch of the Buller River, may be taken, in which some very rich alluvial was worked near the junction. This gold was generally coarse near the lower part of the river; and a similar class of gold was worked as high as Macgregors on the Tiraumea, at which place the conglomerates of the coal measures cease and the head waters of the Mangles flow through granite and slate. It is a remarkable fact that above this point, although there is still a certain amount of alluvial gold obtained, it is in far less quantity, and is much finer than obtained lower down; so that no doubt can exist as to the rocks from which the coarse gold has been derived. Much time has been spent unprofitably by miners in prospecting these Cretaceous coal measures for reefs, it having apparently been overlooked that the gold was probably derived from the conglomerates and simply concentrated, and that the rocks are not such as would be likely to contain reefs.

Later again in the geological history of New Zealand, in fact, during the Upper Miocene period, the land stood at a much higher elevation than at present, and continental conditions, with large rivers, prevailed. During this time the course of the rivers was more nearly north and south than now. The Buller River instead of flowing into the sea at Westport, as at present, delivered itself into Golden Bay near Nelson; the Aorere flowed at a higher level and drained to what is now the mouth of the Parapara; while other large rivers flowed north and south along the west coast, carrying large quantities of shingle with them and depositing thick beds of gravel with small quantities of gold. Remains of these old terrace deposits yet exist; indeed beds of gravel, frequently over 300 feet thick, occur, which have since been cut through by the cross streams now flowing from east to west, and in which most of the rich alluvial deposits have been worked.

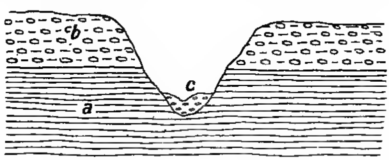


Fig. 30.—*a*, Tertiary marls; *b*, Old river drifts; *c*, Recent alluvial deposits.

These alluvial deposits are represented in the following section (Fig. 30), the wash generally being found on blue marly clays of Tertiary age, which are spoken of by miners as "false bottom." Alluvial

deposits have also been formed by the denuding action of water on reefs in recent times; those which occur on the main or slate bottom are of this order.

The alluvial deposits of Australia and New Zealand may thus be grouped as follows:—

Australia.	*New Zealand.*
Carboniferous conglomerates.	No parallel.
Mt. Poole ? .	Cements of Cretaceous age.
Deep leads of Miocene and Pliocene age.	Miocene gravels of West Coast, only suitable for hydraulic sluicing.
Pleistocene and recent leads on Tertiary bottom.	Recent alluvial deposits on false bottom.
Pleistocene and recent leads on main bottom.	Recent leads on main bottom.
Black sand beaches.	*Beach deposits.*—(*a*) Back leads. (*b*) Black sand beaches.

The beach deposits of New Zealand are almost unique in their occurrence, for, although gold occurs to some extent in similar beds in Australia and elsewhere, they have never been of the importance of those in New Zealand. All along the west coast a heavy current sets to the northward, which during heavy southerly gales is yet stronger. Wherever beaches exist which are exposed to this northerly current there are deposits of alluvial gold found near low-water mark, mixed with black sand. These deposits are worked by means of a portable sluicing table, which is wheeled down to the edge of the sea at low water, a flexible hose being rolled down after it. It is found that after every storm the gold in the sand is renewed. Sometimes the men who own these claims have to wait as much as six months for their deposit of gold to be renewed; but, even under these conditions, they are reported to make good wages at their work. The back leads, which have yielded large quantities of gold, have been formed in the same way, but, since their deposition, have been removed beyond the action of the waves by an elevation of the land.

Alluvial Deposits of British Columbia.—Special attention has been devoted to a description of the Australasian alluvial deposits, because they illustrate nearly every condition which can prevail; but it may be well to allude to British Columbia as affording an illustration on a gigantic scale and exhibiting features which are perhaps better studied there than elsewhere. This mountainous country affords evidence throughout of the important part glacial action has played in shaping its ranges

and forming its lakes. Moraines of great size are found and, in addition to this, the hills are covered over large areas by a glacial till which is sometimes of very great thickness. The "till" carries gold in greater or less quantities, and has been washed by hydraulic power at places where it has been found to carry sufficient gold to make it remunerative. At the present time a good deal of attention is being devoted to testing these deposits, and large areas, as yet untouched, will no doubt be worked in the future. But where these deposits of "till" have been cut through by recent streams, the process of resluicing, already described, has concentrated the gold, and some of the richest alluvial drifts have been formed which have yielded most phenomenal returns. Williams Creek, for instance, in the Carriboo district yielded $20,000,000 in the early days, and many other (although not so rich) deposits have also been worked. The occurrence of rich alluvial deposits under these conditions has, of course, led to prospecting for reefs in the vicinity, but hitherto without much success. It will be self-evident that this is another instance in which the alluvial gold has travelled for some distance from its parent reef, but that, having been transported for the first part of its journey by ice, it has not been greatly worn, hence an inspection of the gold itself would not give any idea of the distance it had travelled.

The following are a few of the conditions which have to be considered in the determination of the value of alluvial deposits. It will be evident that gold may be found under any of the following conditions:—

1. In the beds of rivers; either with shingle in the stream, or as beaches, or in pockets or ledges on the solid rock.
2. Under a cover of a few feet of shingle or surface soil, which may be stripped by hand.
3. As leads below many feet of cover, in which case the ground has to be worked by means of shafts, and the lead blocked out.
4. As poor deposits scattered through large quantities of gravel, in which case the whole deposit has to be sluiced on a large scale.

As regards the two first classes of deposits it is unnecessary to make any further remarks, except to point out that a study of them, and the peculiarities of the rivers which have deposited them, may serve as a guide in following the leads in the third class of deposits.

Gold is deposited by rivers at all points where the current is checked by any means; thus, during floods, when the section of

a river is as follows (Fig. 31), gold is thrown up on the banks, and small beaches are left when the river falls, which can frequently be worked by such simple methods as cradling; but leads have been formed in the main course of the river, and follow the direction in which the main body of the river flowed.

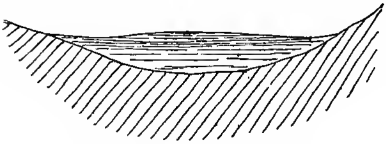


Fig. 31.—Section.

This being the case, a careful study should be made of everything which causes any change in the direction of a river. The following sketch illustrates this, and gives a fair idea of the manner in which beaches are formed, and the gold renewed in these beaches from time to time when the river is flooded.

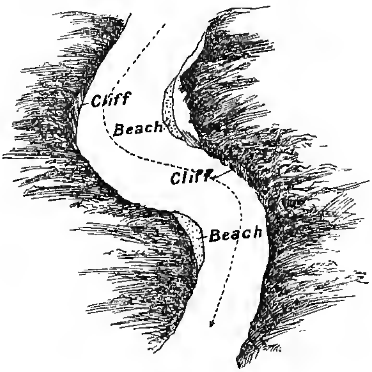


Fig. 32.—Plan.

The principal current would flow down the centre of the course so long as no obstructions were encountered; but when any bluff was met, the direction of the current would be changed and pass from one side of the stream to the other, to be once more deflected on meeting a bluff on the other side of the river. Not only this, but when a river is cutting its bank on one side, it is continually depositing shingle on the other, the section of the stream being as in the accompanying sketch (Fig. 33).

The auriferous deposits will, therefore, be formed in the slack water on the shallow side of the stream, and the leads of gold will follow much straighter lines than the regular course of the stream which deposited them, and, moreover, will not be uniformly rich along the lead.

It is evident that where a close idea can be formed of the former direction of the stream which deposited the leads of gold, much information may be gleaned as to the direction which the richer parts of the leads will take; but unfortunately it is often the case that the surface has been so changed since the deposition

of these deep leads as to make it almost impossible to arrive at satisfactory conclusions. It is only after the leads have been worked that the former course of the river can be traced.

In those deposits, which come under Class 4, no attention

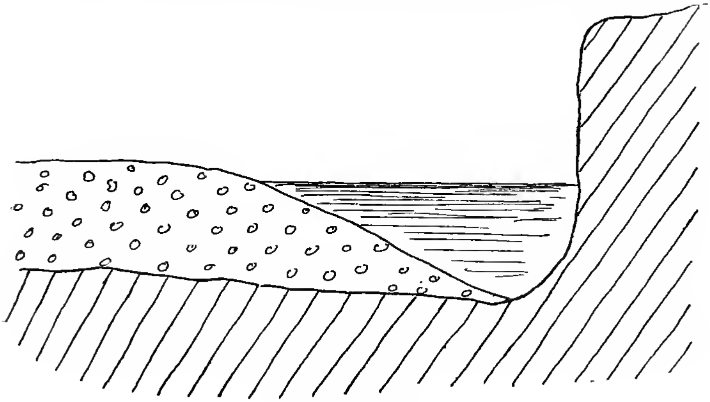


Fig. 33.—Section.

whatever is paid to the distribution of leads of gold; but the whole body of wash is sluiced away on a face, the profits being dependent upon the enormous quantity of material moved. It is chiefly in America that operations of this sort have been carried on, where, on the slopes of the Rocky Mountains, large claims are worked to treat wash dirt from 100 to 200 feet in thickness, in which, it is stated in official reports, as small a return as 2½d. per cubic yard will pay. In cases of this sort there are, of course, several faces opened up for sluicing, and the quantity of water brought in is enormous, while, necessarily, all other conditions must be of a favourable character to enable these low grade deposits to pay dividends on the capital involved. It will be of interest to call attention to the salient points in any such scheme, in order to afford the prospector the opportunity of gauging the chances of success.

Necessarily, the first consideration is the quantity of gold present in the drifts, and the thickness and extent of these drifts themselves. This question should be gauged at the outset by sinking shafts through the drift, and cradling or hand-sluicing everything that is raised from the shafts. By these means the best idea can be obtained of the average yield of the drifts.

When the yield is high, other conditions are of comparatively

little importance; but when low every other feature must be considered in forming an estimate. The quantity of water available must be gauged and the cost estimated of bringing this on to the property; and seeing that the pressure obtainable is an important point, a careful survey will be required to see at what altitude the water can be brought on to the claim. This survey is of the more importance, because by it the only fair estimate can be made of the cost of the race, the amount and height of fluming, where it is advisable to use siphons, and a hundred other small points, all of which bear upon the value of the ground.

The next most important feature, after the value of the gravel and quantity of water have been determined, is what facilities exist of disposing of tailings, or, in technical terms, "what dump exists." This is of great importance, and involves several considerations. When the deposit to be sluiced is situated high up on ranges above the river level, especially if a stretch of unoccupied ground exists between the claim and the river, no possible difficulty can exist; but this is not always the case. Difficulties may arise, either from there not being sufficient fall, or from farmers or others occupying the lower lying ground and objecting to the tailings being deposited upon their property. This has formed so important a matter in the United States as to necessitate an Act of Congress (known as the Debris Act) restricting owners from depositing tailings, except under arrangement, and compelling them to impound them in settling areas when required, and only to allow the clean water to escape.

The difficulty of impounding is not so very serious in the matter of additional cost if a sufficient head of water is available, for by the use of hydraulic elevators the tailings can be raised to 10 or 15 per cent. of the height representing the pressure of water available. When this pressure, however, cannot be obtained the absence of dumping ground will make an otherwise valuable property of no value at all. Even when the tailings can be dealt with by elevators the initial cost of the undertaking is considerably increased if they have to be employed.

Some very extensive operations are conducted at times with the object of recovering the gold in the beds of live rivers, and very often the results achieved are not commensurate with the expenditure. The methods adopted vary a good deal, according to the nature of the river; thus, for instance, on the Molyneux River, in New Zealand, dredging has been very successfully

adopted, bucket dredges being employed, and the material dredged sluiced on the barge. Similar operations are being proposed on the Fraser River in British Columbia. The success of these operations depends to a very large extent upon the facility with which the dredges can be moored, the dangers from rapid rising of the river, and the manner in which operations are conducted. When other conditions are favourable, very low grade gravel will pay for dredging, but it is difficult—indeed, impossible—to estimate what the yield of a river bed will be, except by means of a dredging plant, so that the expense of a dredge has to be incurred for the purpose of prospecting. It is true that some idea may be gained by testing the river bed at low water, or even by running out wing dams. Tests are also made by divers, and occasionally by bore holes; but these can never be relied upon as giving accurate results. Hence some speculation must always attend the first operations in dredging a river. In other cases a river is diverted, and its original bed laid dry; and in others again, by the construction of crate dams down the centre of the stream, and the deflection of the river to one or other side, one-half of the river bed at a time is rendered available for sluicing operations. Great danger exists in these cases from floods, and it is by no means an unusual thing for the work of months to be carried away in a night, many promising enterprises having thus been brought to an untimely end.

Alluvial deposits, it will be seen, include forms of mining which vary from the most primitive methods of washing with a tin dish, cradling or hand sluicing, to operations which involve the expenditure of large quantities of capital, and tax the energies of the best hydraulic engineers to bring them to a successful issue.

CHAPTER X.

NOBLE METALS.

Gold—Platinum—Osmium—Iridium—Palladium—Tellurium.

Gold.

Distribution.—Gold is more universally disseminated in nature than is generally supposed, although there are only a few fields in the world where it is abundant. Australia has hitherto proved the richest goldfield, California coming next on the list, but South Africa promises to eclipse all other countries in the future.

Its general mode of occurrence is, like platinum, in the native state; but, unlike that rare metal, gold is found in association with many ores, especially sulphides. Gold occurs in actual combination with tellurium only; there are tellurides of gold, of gold and silver, gold and lead, &c.

Mode of Detection.—There is very little difficulty in recognising gold, although many curious mistakes are made by men who have had no experience, specks of copper pyrites in quartz and even small yellow flakes of mica being at times taken for the precious metal. Gold, however, remains of the same colour in every light, is metallic, and can be cut with the point of a knife; whereas, other minerals are brittle; moreover, it is not affected by acid other than nitro-muriatic acid. The prospector, however, soon gets so well acquainted with its appearance as to hardly ever make a mistake; if the stone be crushed and washed, the gold will be very readily recognised in a tin dish in which, if any doubt exists, it can be amalgamated with a little mercury.

Association with Sulphides.—Although gold is almost universally present in iron pyrites, it is not, in most cases at

any rate, in actual combination with sulphur ; but is only disseminated through the pyrites in the metallic state, or intercalated in minute scales between the crystalline layers of that mineral. Gold is also found mixed with copper pyrites, galena, zinc blende, mispickel, stibnite, magnetic pyrites, and cinnabar, all of which are sulphides. It is often found in company with native bismuth, magnetic iron, hæmatite, barytes, apatite, fluorspar, and siderite; but its most universal matrix is quartz, although calcite or dolomite more rarely form the gangue.

Auriferous Belts.—The most usual mode of occurrence of gold is in reefs, from which alluvial deposits are derived. In the richest and most celebrated gold-mining districts these reefs do not occur singly, but in belts. The reefs in the two most important mining districts of Victoria at Ballarat and Sandhurst, which lie to the south and north of the dividing range respectively, form two well marked mineral belts. In New South Wales there is an important, though not so well marked, belt which extends north and south of Bathurst ; and in California the whole of the auriferous veins of the Sierra Nevada can be considered as a great auriferous belt.

In each of these cases the main trend of the belts is north and south ; but there are many auriferous reefs occurring in them which strike in other directions, especially east and west, or at right angles to the principal veins, and these are called cross-veins or cross-courses. In Victoria the number of cross reefs is probably not one-tenth of the total number of reefs known, but in New South Wales they are of more frequent occurrence.

It is importaut to study the course of the greater number of reefs in any district, because the dispersion of gold in alluvia is most abundant in regions where the drainage system corresponds with their strike, rivers flowing at right angles across the general direction of the reefs not having abraded them over so extensive an area.

Gold in Eruptive Rocks.—Auriferous veins occur most frequently either in or associated with eruptive rocks. In Transylvania eruptive rocks of Tertiary age are traversed by veins containing pyrites, gold, and other minerals, sometimes silver, and sometimes the rare metal tellurium combined with gold, gold and silver, or gold and lead. Other veins which cross the main lodes appear to have exerted a favourable influence on them.

The most important eruptive rock in which the precious metal occurs is the so-called propylite, an altered variety of andesite which occurs in some of the Transylvanian mines, and which is

the enclosing rock of the Comstock lode ; the same rock is also found at the Thames in New Zealand.

In the Ural Mountains gold also occurs in eruptive rocks. In the district of Berezowsk, in the Southern Urals, crystalline schists have been traversed by dykes of a fine-grained variety of granite, parallel in strike with the direction of the mountain chain. This variety of granite, especially when it is in contact with the lodes, contains iron pyrites altered and decomposed to limonite. At right angles to the dykes innumerable quartz veins occur, from 1 inch to 3 feet wide, containing gold, iron pyrites, &c., but they have not proved very remunerative. Gold also occurs in the same district in quartz veins traversing diorites, serpentines, &c.

The auriferous belt of California extends along the lower slopes of the Sierra Nevada, which is formed of granites, flanked by crystalline schists and other rocks up to the Jurassic. It consists of quartz veins striking in the same direction as the beds, and containing numerous metallic sulphides which all carry gold.

One of the most remarkable gold veins in California is the great mother lode, which extends for a distance of over 70 miles, with a thickness varying from 6 feet to over 60 feet. In some places it outcrops like an immense white wall, but is not always remunerative.

Bedded Veins.—The Véta Madre in Mexico is a vein coinciding with the strata, and is considered to be a bedded vein, the dip of both the lode and rocks being about 45°. It attains at some places a thickness of 150 yards, and occurs at the junction of clay slates and conglomerates which are supposed to be, the former, of Devonian and, the latter, of Triassic age. The veinstone is amethyst quartz with calcspar, enclosing fragments of the country rock. Gold, silver, and silver glance are the principal ores; but numerous other minerals occur, including the common sulphides.

In cases of this sort where ore deposits, are for a part of their course, regularly interstratified between the beds, it is difficult to avoid using the term "bed" to describe them ; and, indeed, it is quite possible that such deposits may in some cases have been formed as beds in a similar manner to the banket beds of the Transvaal already described. When the term "bedded veins" is employed it must be understood that their formation is attributed to the same origin as that of true veins, and that they have not been formed contemporaneously with the strata in which they are enclosed.

It must be clearly understood that, although auriferous quartz veins are generally associated with eruptive rocks, perhaps the greater number of reefs traverse sedimentary strata which have also been intersected by dykes.

Reefs traversing Sedimentary Beds.—In Victoria, where careful observations have been made and records kept, the auriferous quartz veins which traverse the lower Silurian rocks are considered to be richer than those which occur in the upper Silurian; those in the lower Silurian also strike more nearly north and south than those in the upper part of the system. Cross reefs striking east and west are comparatively rare.

The reefs in New South Wales are generally smaller and richer than those in Victoria. They occur mostly in the upper Silurian and Devonian systems, and cross reefs are more frequent than in Victoria.

Reefs associated with Diorite.—In all the Australian Colonies, as in other parts of the world, eruptive rocks are frequent associates of gold-bearing veins; but in Victoria the mode of occurrence is somewhat peculiar, dykes of diorite sometimes lying alongside auriferous reefs, and in other places intersecting and sometimes heaving them.

An interesting instance of this class of deposit occurs at the Wentworth goldfield, near Orange, in New South Wales, where the gold seems to be partly held in solution by mispickel, from which it exudes when heated in the shape of moss-like excrescences (Liversidge, *Trans. Royal Soc., N.S.W.*, 1876).

According to the late Mr. C. S. Wilkinson, the auriferous deposits occur at the junction of serpentine with a felspathic rock containing hornblende (hornblendic felsite), which in some places passes into diorite. Along this line of junction is what the miners term the "lode," which, at the surface, is a fissure 6 feet or more in width, extending in a direction nearly north-west and south-east for a distance of 50 chains. It is filled with a red sandy ferruginous clay containing hard siliceous accretions of irregular shape, locally termed "clinkers." It underlays to the north-east at an angle of about 65°, though in some places it is nearly vertical. The hornblendic felsite forms the footwall, and the serpentine the hanging wall.

Shoots.—In the felsite at varying distances along the "lode" are quartz veins from a few inches to 6 feet thick, coming in from the west and abutting against the lode, which they appear to follow down, forming irregular quartz "pipes" or "shoots," which dip diagonally in the lode towards the east. These veins have only been found to contain payable gold when they

junction with the "lode" and form shoots, which are also called "bonanzas."

The Wentworth field affords an illustration of the influence exerted by cross veins in determining the dip of shoots of gold in the reefs, but in many other localities, especially where the rocks are dipping at moderate angles, and are of different degrees of hardness, the rich parts of the lode will be determined by the intersection of the lode and a belt of congenial or "kindly" country. It is of the greatest importance to discover the laws which govern the distribution of the rich parts in reefs, and the causes which have influenced the dip of the "pay shoots." Although the laws which have been enunciated in the chapter on fissure lodes will not always explain all the peculiarities of a field, they will form the basis on which to work; and, when considered in conjunction with any local peculiarities which may exist, will generally give valuable

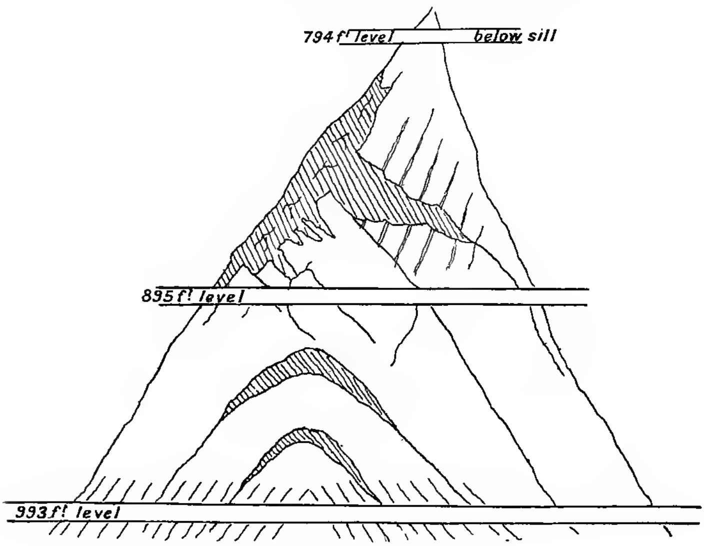


Fig. 34.—Section.

results. A careful record of the work in a mine, showing, in addition to the direction of the levels, the distribution of the rich parts worked, and any changes in the rocks, or intersections

of veins, will afford most valuable hints as to the direction which future workings should take. These details unfortunately are seldom shown on the plans of mines.

Saddle Reefs.—A class of reefs not hitherto described in these pages, which are called "saddle reefs," occur at Sandhurst, Victoria. The foregoing sketch (Fig. 34) gives an idea of their shape, and at the same time suggests that they may have been formed at the intersection of a parallel system of fractures with cross-joints in the rocks; but it has also been suggested that they are due to foldings of the strata.

The richest parts are said to be at the caps of these reefs; the branches (which are called the eastern and western legs respectively) being relatively poor, although generally one of these legs will pay to work for some distance down, while the other is barren. Many of these saddles are found one below the other, as shown in the sketch, and they are only developed by sinking.

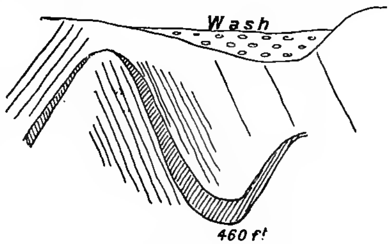


Fig. 35.—Section.

It is not in Sandhurst only that reefs of curved shape occur; at Clunes, for instance, there are several saddle reefs. The adjoining section shows the shape of one of them, which seems to be a vein of segregation in the folds of an anticline to the west, and of a syncline to the east. In the place where this section has been taken, the alluvial wash is covered by 84 feet of gravel, 142 feet of basalt, and 15 feet of surface soil (Fig. 35).

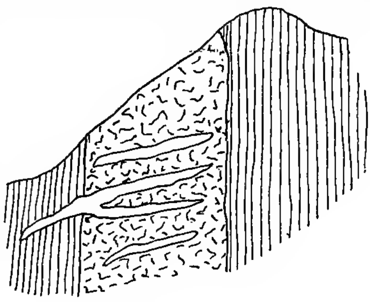


Fig. 36.—Section.

Flat Veins.—In Gippsland there are some interesting veins of segregation which are illustrated by the accompanying sketch. They are called "flat veins," and occur in dykes of diorite porphyry, which, for a certain depth from the surface, are decomposed to clay. The quartz is very rich in the soft, decomposed matrix, but when the undecomposed rock

is reached in depth, the quartz appears to become poor, or to run out.

Gold in Itacolumite.—In Brazil, gold occurs under exceptional circumstances in beds of metamorphic sandstone, which is sometimes flexible, containing mica, micaceous iron, and other minerals, and forming lenticular masses in a formation which is supposed to belong to the Lower Silurian or Cambrian period. This sandstone, which is called "itacolumite," not only contains gold, but also diamonds, rutile, tourmaline, &c. The gold is always alloyed with silver and copper, and sometimes with platinum.

Gold in Pyrites.—The occurrence of both copper and iron pyrites containing gold at Borsa-bánya in the northern Carpathians, at Barraneos, in Portugal (where it is also associated with black oxide and other ores of copper), and some other localities deserves to be mentioned.

Gold in Timazite.—At Borsa-bánya, besides some trachyte, there is a peculiar labradorite rock, called timazite or hornblende andesite, which traverses both the mica schists and Carpathian sandstone. A whole mountain is formed of this timazite, in which a certain number of veins occur nearly parallel to one another. Copper pyrites and iron pyrites, with little quartz, compose the filling of these lodes, and are both auriferous, and iron pyrites is also disseminated through the timazite.

Gold in Transylvania.—At Rodna, Transylvania, gold and silver occur with sulphides in a vein of calcspar and quartz in a contact deposit. The country consists of mica schist, hornblende schist, granular limestone, and Tertiary deposits, traversed by dykes of andesite. When these come in contact with the limestone the ore deposits occur.

Gold in Nevada.—In the Eureka district, Nevada, a great ore channel extends along the eastern base of Prospect Mountain for a distance of 12 miles. This appears to be a contact deposit in beds of limestone, quartzite, shale, &c. The ore contains gold, silver, and lead, and some of the mines have yielded a considerable return in bullion.

Breccia Lode.—Before concluding this branch of the subject there are some exceptional modes of occurrence of gold which should be described. The first of these is at Browns Creek mine near Blayney, New South Wales, described as an immense breccia lode, in which the gold is disseminated in fine particles. The vein stuff is a ferruginous flinty rock, with concretions of chalcedony and the country rock is limestone penetrated by dykes

of grey diorite. It has been stated that this deposit shows evidence of segregation or deposition from hot springs which probably accompanied the diorite eruption.

Another remarkable deposit which occurs at Belubula, New South Wales, has already been described in the chapter on stratified deposits; but the most remarkable deposit of all is that of Mount Morgan in Queensland of which the following description by Mr. R. L. Jack published shortly after its discovery is of interest.

The summit of Mount Morgan is composed of what Mr. Jack calls a sinter deposit, and he says, in his report on the district:—"Down the hill sides to the north, west, and south a similar deposit is everywhere met with; a frothy or spongy matrix, sometimes aluminous and sometimes siliceous, generally iron-stained and occasionally associated with large masses of red and brown hæmatite, but gold has as yet only been obtained from a few places away from the hill top, although, naturally, there has been vigorous prospecting (so far as possible in an unusually dry season) wherever the 'formation' resembled that of Mount Morgan."

In describing the deposit he says:—"The frothy and cavernous condition of the siliceous sinter of Mount Morgan may be accounted for by the escape of steam, while the silica was yet (after its deposition on the evaporation of the water) in the gelatinous condition so frequently observed in the deposits of hot springs. The aluminous silicates represent the familiar outbursts and flows of mud. The iron oxide appears to have been deposited in some cases along with the silica and alumina, and in others to have been deposited later, its solvent fluid having been, as it were, injected into the interstices, vesicles, and caverns of the silica and alumina. In some cases it may have been originally pyrites, as it now and then occurs in cubical hollows. Calcareous sinter is very common in siliceous springs, and its absence from Mount Morgan must needs imply the local absence of limestones among the rocks from which the spring was fed. The silica would be found abundantly in the quartzites, and the alumina may have come in part from a deep-seated underlying granite. The gold, and to some extent the iron, may have been dissolved out of the iron pyrites of such reefs as the 'Mundic Reef' seen in Mundic Creek; the gold possibly by chlorine produced by the contact of hydrochloric acid, derived from the decomposition of chlorides, with manganese, which occurs sparingly in the form of pyrolusite along with the ironstone of Mount Morgan."

It is doubtful whether Mr. Jack was correct in his views regarding the origin of this deposit; for a lode decomposing near the surface, especially if highly charged with pyrites, would present very similar phenomena, and later developments have demonstrated the pyritic nature of the lower levels, the pyrites being associated with quartz (see also p. 104).

Gold in Deep Leads.—The occurrence and distribution of gold, &c., in alluvial deposits has formed the subject matter of another chapter, but a few remarks may be added on deep alluvial deposits.

It should be borne in mind that in those places where deep alluvial leads have been covered by flows of basalt they have had the best chance of resisting denudation, and it is to the protection thus afforded that the deep leads of Australia owe their preservation. It is evident that such leads are not likely to exist in flat country; but will generally occur either on the slopes or at the foot of high ranges. In many cases where the alluvia of the valleys have been thus buried and protected, the rivers have been compelled to cut fresh channels for themselves.

Most of the deep leads of Victoria have been buried in this way, and at Ballarat there are no less than four distinct beds of basalt, below each of which a bed of auriferous drift occurs. These different flows of basalt are known as the first, second, third, and fourth rocks respectively, and they are represented in the following sections, taken from Brough Smyth's *Australian Goldfields*, 1869:—

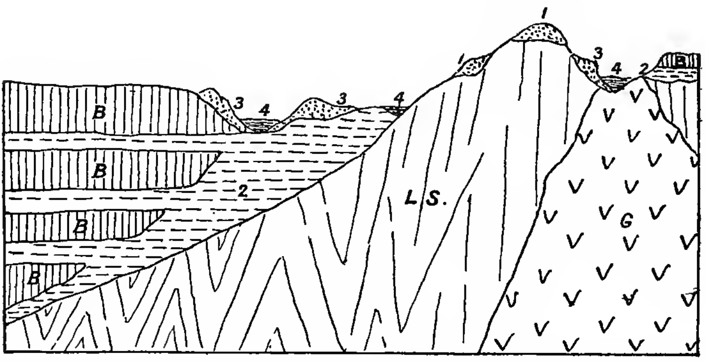


Fig. 37.—Section at Ballarat.—G, Granite; L S, Lower Silurian; B, Basalt. 1, Older Drift; 2, Newer Pliocene Drift; 3, Recent; 4, Most Recent.

In the following section taken from the same work, a valley has been formed by denudation of the drift. On one side of the valley the drift is overlain by basalt, but is uncovered on the slope of the opposite bank (Fig. 38).

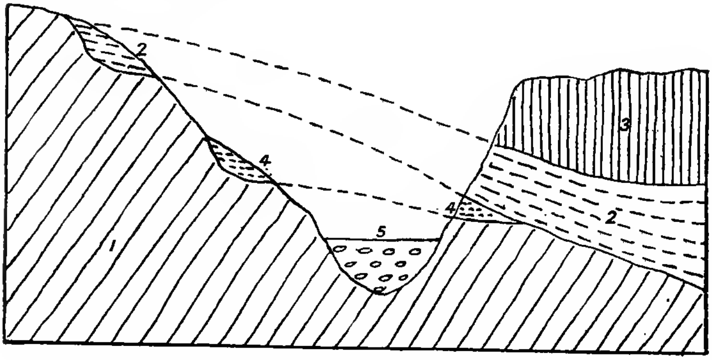


Fig. 38.—Section.—1, Silurian Strata; 2, Auriferous Drift; 3, Basalt; 4, Newer Pliocene Drift; 5, Recent Drift.

Denudation has frequently worn away the beds, so as to leave hills capped with basalt, as on the slopes of the Sierra Nevada. The gravels seldom lie on a flat bed rock, but generally on a concave, basin-like surface, the edges of which are, in California, called "rim rock," the term "bed rock" being reserved for the bottom of the depression. Tail races, or sludge channels, are frequently driven through this "rim rock" in order to work the low-lying parts of the drift, as in the section (Fig. 39).

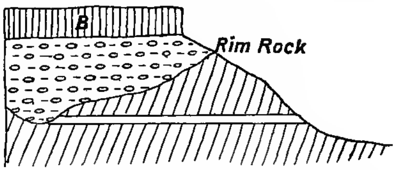


Fig. 39.—Section.

Platinum and Allied Metals.

Platinum, the least fusible of the metals, occurs in alluvial deposits in small grains, together with some other very rare metals such as osmium, iridium, and palladium. It is often found with gold, as in the Urals, which district produces nearly all the platinum used in the World. In other countries it occurs in relatively small quantities, as in New Zealand and

New South Wales; and a fair quantity has been found in some parts of California, although no steady yield has been obtained there, probably due to a large extent, to the fluctuations in value making the search for it seldom remunerative.

In New South Wales, a nugget of 268 grains—over half an ounce—is reported to have been found, at Wiseman's Creek, with alluvial gold; but it was no doubt very impure, having a specific gravity between 15 and 16 only.

Although of comparatively little importance, some of the metals usually associated may be mentioned. Iridosmine, especially, is stated to occur commonly with alluvial gold in New South Wales, usually in minute grains or scales, and it is also mentioned from New Zealand.

It may be remarked in connection with these minerals that platiniridium and iridosmine are even heavier than platinum itself, as seen in the table; and that they are at the same time the hardest metals, being as hard as quartz; so that they are easily distinguished from platinum, which is malleable, and of the same specific gravity as gold. Platinum has never been mined except in alluvial deposits, but from its association in the Urals with chrome iron and serpentine, it is inferred that, in this country at least, it occurs in serpentine. In the neighbourhood of Broken Hill, New South Wales, it has been found associated with a lode, but has not been worked.

TABLE OF NOBLE METALS.

Mineral.	Composition.	Hardness.	Specific Gravity.	Colour.	Remarks.
Electrum, .	Gold with 20°/₀ silver	$2\frac{1}{2}$-3	14	Very pale yellow	Malleable and ductile.
Gold, . .	Always with more or less silver, &c.	$2\frac{1}{2}$-3	15·6-19·4	Yellow	Malleable and the most ductile of all the metals.
Platinum, .	Pt with Ir, Pd, &c.	4-5	17-21	Steely-white	Malleable when pure.
Platiniridium,	Pt, Ir	6-7	22-23	White	...
Iridosmine, .	Ir, Os	7	18·8-21·2	Tin-white or lead-grey	Malleable with difficulty.
Palladium, .	Pd with Pt and Ir	$4\frac{1}{2}$-5	11·5	Whitish steel-grey	Ductile and malleable.

Pt, platinum. *Ir*, iridium. *Os*, osmium. *Pd*, palladium.

Tellurium Minerals.

Tellurium is the only metal which has hitherto been found in nature in actual chemical combination with gold. It also occurs in a native state, and, combined with other metals, forming tellurides.

The most important of these are included in the following table, but tellurides of mercury, bismuth, lead, and nickel also exist:—

TABLE OF TELLURIUM MINERALS.

Mineral.	Constituents.	Metal per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Tellurium,	Native	Small proportion of gold	$2\frac{1}{2}$	6	...	Tin-white, very fusible, burns with a greenish flame — very rare.
Nagyagite,	Te, Au, Pb	Au 9	1	7	Blackish lead-grey	Lead-grey, very fusible, gives a blue colour to the flame – rare.
Hessite, .	Te, Ag	Ag 62	$2\frac{1}{2}$-3	8·5	...	Lead-grey, malleable—rare.
Petzite, .	Te, Au, Ag	...	$2\frac{1}{2}$	8·7–9	Iron-black	Sometimes tarnished.
Sylvanite or graphic tellurium,	Te, Au, Ag	Au 26 Ag 11	$1\frac{1}{2}$-2	8	Steel-grey to silver-white	Steel-grey, sectile, gives the flame a greenish-blue colour.
Calaverite,	Te, Au	Au 40 Ag 3	...	..	Yellowish-grey	Massive, bronze-yellow, brittle, bluish-green flame.

Te, Tellurium; *Au*, Gold; *Ag*, Silver; *Pb*, Lead.

The most common of these minerals, petzite and sylvanite, are of fairly common occurrence in Colorado, more especially at Cripple Creek; in the gold and silver mines of Transylvania; and, more recently, they have been discovered in some considerable quantity in the Hannans or Kalgoorlie District of Western Australia. In this last-mentioned locality they are found, as

the permanent ore, in depth below the zone of decomposition near the surface.

Above this line of decomposition, some very rich ferruginous quartz lodes occur, and the gold is very fine—in some cases looking like mustard disseminated through the matrix, and only exhibiting its metallic lustre when burnished.

Tellurides constitute exceedingly valuable ores when they are sufficiently rich to allow of hand picking and sale to smelters, and even the poorer ores can be treated by roasting and either chlorination or cyanidation. In many cases attempts to concentrate have been unsatisfactory, as the mineral frequently slimes a great deal; but concentration is said to have been successfully applied in Boulder County, Colorado, and the possibility depends to a great extent upon the nature of the ore.

Specimens are found in many localities, but it is in comparatively few places that workable deposits exist.

CHAPTER XI.

SILVER AND LEAD.

Silver occurs under two very different conditions; the first as silver minerals or ores, the second as ores of lead or copper in which more or less silver is present.

As the simplest means of extracting silver is by smelting with lead ores and desilverising the lead thus obtained, it is obvious that when no lead is contained in the ore itself it will be necessary either to mix lead ores with it, if smelting is to be resorted to; or else adopt a different method of treatment. Those silver-bearing lodes which do not contain lead are spoken of as "dry ores."

It will be seen that the ores of the first class may be directly recognised, either by their appearance or blowpipe characters; whilst the second class will only disclose to assay whether or no they contain silver in sufficient quantity to be of value.

The silver ores proper all yield a bead of silver when treated before the blowpipe, on charcoal, with carbonate of soda; the most common of them are given in the following table :—

TABLE OF SILVER ORES.

Mineral.	Combined with	Silver per cent.	Other Metals.	Hardness.	Specific Gravity.	Streak.	Remarks.
Native Silver,	...	100	...	...	...	...	... ...
Argentite (silver glance),	S	87	...	2-2·5	7·4	Shining	Perfectly sectile, crystals usually shrivelled.
Stromeyerine,	S	53	Cu 31 °/。	2-2·5	7·3	Black	Deep lead-grey.
Sternbergite,	S	33	Fe	1-1·5	4·2	Do.	Rare — gives a magnetic globule from presence of iron.
Stephanite brittle sulphide,	S, Sb	68	...	2·5	6·3	Shining	Tabular crystals, iron-black.
Polybasite, .	S, Sb, As	64	Cu 10 °/。	2·5	6·2	Black	Do.
Pyrargyrite, .	S, Sb	60	...	2-2·5	5·8	Red	Dark ruby-silver.
Proustite, .	S, As	65	...	2-2·5	5·6	Do.	Light ruby-silver.
Kerargyrite (horn-silver),	Cl	75	...	1-1·5	5·4	Shining	Products of decomposition occurring generally in crusts, coatings, and cauliflower-like excrescences, rarely in minute crystals.
Bromargyrite,	Br	57	...	1-2	6	Yellowish-green	
Iodargyrite, .	I	46	...	1	5·6	Yellow	
Embolite, .	Cl, Br	66	...	1-1·5	5·4	Yellow or green	

S, Sulphur; *Fe*, Iron; *Cu*, Copper; *Sb*, Antimony; *As*, Arsenic; *Cl*, Chlorine; *Br*, Bromine; *I*, Iodine.

The preliminary examination with the blowpipe having determined that a mineral belongs to this group, it is practicable in some cases to decide by simple inspection which of the foregoing minerals it is; but in others it is necessary to apply certain tests in order to discriminate between them, and the following notes will be of service :—

Native Silver is not likely to be mistaken for anything else, its malleability and white characteristic colour being sufficient for its determination. It will be distinguished from platinum by being fusible before the blowpipe, while platinum is not. It might be confounded with one of the native silver amalgams, but these are rare. One of these, called "amalgam," contains

about 30 per cent. of silver, is brittle and generally is found either massive or as coatings; while another, called "arquerite," contains 86 per cent. of silver and is malleable. It often occurs in crystals, whilst native silver is generally found in strings, branches, or dendritic crystals. Native silver has never been worked in alluvial, and is not likely to be found in this kind of deposit; although its occurrence is not impossible.

Argentite is fairly abundant and, being of great value, is important to recognise. Its surface is usually tarnished, but it may be cut like lead and then appears of a bright lead colour. It is so easily fusible that it will melt if brought near to the flame of a candle. Grey copper, especially when tarnished black, might be mistaken for silver glance as it has the same external appearance, but, in addition to the characters already mentioned, silver glance will not give antimonial fumes, nor the smell of garlic due to arsenic before the blowpipe. There is also a great difference in weight, the specific gravity of argentite being about 7, whilst that of grey copper is about 5.

Some cobalt ores will be distinguished from silver glance in that they are more or less brittle, at least not malleable or sectile; infusible in the flame of a candle; and yield a blue bead with borax before the blowpipe.

To distinguish silver glance from copper glance or bournonite the blowpipe reduction assay on charcoal with soda is necessary, as they are both easily sectile and fusible; the first will give a silver, the second a copper bead. This distinction, however, will be made before the mineral is included in this group.

Stromeyerine.—The lustre and colour of cupriferous sulphide of silver are the same as those of bournonite and some grey copper ores; but these will emit white fumes and a smell of garlic before the blowpipe, while stromeyerine will not. This mineral, however, may be difficult to distinguish on account of the presence of copper, and an assay may be necessary.

Stephanite, being brittle, will be easily distinguished from silver glance, which is sectile. From black oxide of copper it will be distinguished by the reduction of the metal on charcoal with carbonate of soda, and from polybasite by the absence of arsenic.

Pyrargyrite and **Proustite,** the two ruby-silver ores, will be distinguished from one another by their streak, that of proustite being lighter in colour, and by their different behaviour before the blowpipe; pyrargyrite yields fumes of antimony, proustite the smell of garlic. They are each, however, liable to be confounded with other ores.

When crystallised they resemble specular iron or hæmatite, but may be easily distinguished; for iron ores will not melt before the blowpipe alone, while the silver ores will, and at the same time emit the characteristic fume. Another ready test will be that of hardness, specular iron being scratched with difficulty by a knife, while the silver ores yield easily to it. Specular iron also becomes magnetic on charcoal before the blowpipe. From copper glance they will be distinguished by the colour of the streak, as also from polybasite.

When compact the ruby-silver ores sometimes resemble realgar, cinnabar, and red oxide of copper in appearance, but will be distinguished by the colour of the streak, which is cochineal-red for ruby silver, orange for realgar, scarlet-red for cinnabar, and brown-red for oxide of copper; the distinction from cinnabar, however, will be doubtful.

Before the blowpipe cinnabar entirely disappears, as it is composed of sulphur and mercury, both of which are volatile.

Pyrargyrite occurs sometimes of a lead-grey colour, when it resembles silver glance, copper glance, and bournonite; but the streak will in all cases be sufficient to remove any doubt.

Kerargyrite, or horn silver, presents the appearance of wax, and is as readily cut; so will be easily recognised. The newly-cut face soon tarnishes and becomes greyish-violet on exposure to light. Rubbed on wet iron, zinc, or copper, horn silver yields a coating of silver, and blocks of this mineral sawn through with a steel saw show silver coatings on either face.

Bromargyrite is similar in character, but is generally of various shades of green.

Iodargyrite is often earthy and yellow, and, consequently, resembles some earthy oxides, such as those of lead, bismuth, antimony, and molybdenum; but these always accompany the metals from the alteration of which they are formed. The blowpipe test will ascertain the nature of the yellow powder.

The study and discrimination of silver ores is very important, for not only are they interesting in consequence of their value, but several compounds in which silver exists are not easily recognised. As it often happens that a small quantity of a rich silver mineral, disseminated in grains through an ore, is sufficient to make that ore very valuable, it is most desirable for the prospector to thoroughly accustom himself to the recognition of such minerals; as a failure in this respect may result in his missing a valuable discovery.

As an illustration, it may be mentioned that small grains of argentiferous mispickel occur disseminated through some galenas,

which are, in consequence, very rich; and it is also well known that silver chloride in large proportions is often found in an earthy matrix which would generally be disregarded. Such is the case with the rich chlorides of silver scarcely visible in the so-called "pacos" and "colorados" of Peru, and in the gossan at the outcrops of many silver-bearing lodes.

Valuing Silver Ores.—Native silver often occurs accompanying other silver ores, and is sometimes sufficiently abundant to form its most valuable constituent, as at Kongsberg, in Sweden, and in Peru. Argentite or silver glance, which is the sulphide of silver, is perhaps the most important of the ores of this class; but the antimonial silver ores also occur in considerable abundance in certain localities, notably in some of the American mines. The chlorides and chlorobromides of silver are also, at times, of importance; but as they are essentially ores of decomposition, are seldom found at any great depth from the surface. In the gossan of many silver-bearing lodes they are abundant and of great value, and are also at times found disseminated through andesitic and rhyolitic rocks, as in the Calico District of California.

A simple, but rough, method is sometimes adopted of testing the value of ores from day to day when chlorides are the minerals chiefly worked—viz., by powdering the ore in the mine, mixing it with a solution of hyposulphite of lime, which dissolves the chloride, and then adding sodium sulphide, which forms a dark-coloured precipitate if much silver is present. It is evidently impossible to estimate in this way the contents of silver, but it affords a very good test whether the ore is of value or not.

Some rich silver ores are very brittle, especially those containing antimony and arsenic, and great care is necessary in the process of taking average samples, or unreliable results will be arrived at. Care is also necessary in working the ores on a large scale to see that all the dust produced is saved for treatment, as this is frequently the richest part of the ore.

Many silver deposits in America, along the Cordillera (both to the north and south), and in Europe, especially in Transylvania, are connected with some peculiar kinds of eruptive rocks belonging to the group of andesites, and spoken of as propylites. This rock occurs at the famous Comstock lode in Nevada, where not less than a dozen varieties of eruptive rocks, andesites, propylites, &c., belonging to three different epochs of eruption, form the accompaniment of this rich deposit. A better opportunity could not be selected for again directing the attention of prospectors to the important connection which may be observed

between the eruptive rocks and their metalliferous contents, and to the importance of studying their connection carefully. It may be added that some of these deposits are of very recent origin, as the rocks of the andesitic family have been chiefly erupted during tertiary times.

The silver ores of the second class mentioned at the beginning of this chapter are those which occasionally carry silver, and then come under the class of argentiferous ores. These may be enumerated as follows:—

Galena (sulphide of lead). See *Lead.*

Bournonite (sulpho-antimonide of lead and copper). See *Copper.*

Tetrahedrite (antimonial grey copper). See *Copper.*

Tennantite (arsenical grey copper). See *Copper.*

Mispickel (arsenio-sulphide of iron).

Zincblende (sulphide of zinc). See *Zinc.*

The above minerals, when argentiferous, do not give evidence of the presence of silver, unless they are submitted to the process of assay. A very simple test for the presence of silver in ores, however, is mentioned in Charles H. Aaron's *Practical Treatise on Testing and Working Silver Ores*, and is as follows:—"The ore should be ground fine, and then a few ounces are mixed with about one-tenth of its weight of salt, and one-twentieth of copperas. This is placed in an old frying pan, and heated gently so long as a smell of burning sulphur can be noticed, the mass being stirred with a thin bar of iron all the time. After all the sulphur has been driven off, the heat is increased for a few minutes to a light red, and the mass stirred until it swells up and becomes sticky, care being taken not to fuse the ore. The mass is then taken out, and allowed to cool on a rock, and after a little more salt has been added, and the ore mixed with water to the consistency of mortar, a strip of sheet copper, previously cleaned, is inserted, and left there for ten minutes. The copper is then removed, washed in clean water, and if any silver is present, it will be coated with a white substance, which will be heavier or lighter, according to the richness of the ore, and, if very rich, will appear grey and rough. The frying pan should be smeared with clay or mud, and dried before being used."

Silver exists in traces, or in larger proportions, in all galenas; but an assay is the only way to ascertain the percentage, as there is no physical character to distinguish the poor from the rich argentiferous galenas. It has often been stated that galenas with small crystalline facets, like coarse lump sugar, are rich in silver, while those with large cleavages are poor; but

this character at best is only local, for some galenas with large cubical cleavages yield as much as 1,500 ozs. of silver per ton, whilst other fine-grained ores contain 50 ozs. per ton, or even less.

Argentiferous grey copper and galena, accompanied by the different arsenical and antimonial silver ores, form the chief characteristic of the silver mines of Saxony and Bohemia.

Lead Ores.

All ores of lead give a bead of metallic lead when heated on charcoal with soda before the blowpipe. They will be readily distinguished one from the other by the characters given in the following table:—

TABLE OF LEAD ORES.

Mineral.	Composition.	Metal per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Galena, . .	Sulphide	80	$2\frac{1}{2}$	7·6	Lead-grey	Metallic lead-grey; cubical cleavages or granular.
Minium (red lead),	Oxide	90	2–3	4·6	Dull-yellow or bright red	Not common, found with galena; orange-yellow to red.
Cerussite, .	Carbonate	77	$3-3\frac{1}{2}$	6·4	White or greyish	White to grey; decrepitates and fuses.
Anglesite, .	Sulphate	68	$2\frac{1}{2}-3$	6·2	White, grey, or black	Not common.
Crocoisite, .	Chromate	64	$2\frac{1}{2}-3$	6	Orange yellow	Colour red; blackens and fuses when heated.
Pyromorphite,	Phosphate and chloride	76	$3\frac{1}{2}-4$	6·5	White or yellowish	Various colours, yellow, red and green; swells up and changes colour when heated.
Mimetite, .	Arseniate	48	$3\frac{1}{2}$	7·2	Light yellow	Lustre adamantine; generally covered with a black coating of arsenic; faces of crystals curved.

Lead mining in Europe is inseparable from silver mining, as silver is mostly extracted from argentiferous galena; cheap labour and scientific appliances enabling poor ores, containing only 9 or 10 ozs. of silver per ton, to be treated at a profit, both lead and silver being extracted.

In America, where the production of silver is enormous, the proportion of galena mined to silver ores proper is relatively small, and the economic conditions are not so favourable to a large production of lead, a metal of comparatively little value.

Galena.—Galena is found in abundance throughout Australia, but up to the present time only those ores which are rich in silver have received much attention. The immense deposits of comparatively poor ores, however, of which the best illustration is to be found in the Broken Hill mines, are being worked, and doubtless as time goes on, and still more economical appliances than those now in use are introduced, still poorer ores will be worked.

The most troublesome feature about the Broken Hill ores has been the association of zincblende with the galena, more especially because the silver is associated with each mineral, so that no process of concentration is of value in enriching the ore. A very ingenious process has been devised by Mr. Ashcroft for dealing with this class of ore and is now in operation. A brief description of the process may be of interest. The mixed ore, consisting of galena and blende is first roasted so as to desulphurise a portion of the blende, leaving an amount which is determined by circumstances still unaffected. The roasted ore is then leached with ferric chloride, the zinc being dissolved as chloride, leaving the silver behind and the iron taking the place of the zinc as hydrate. The zinc is subsequently precipitated by electricity, an iron anode being employed, and the ferric chloride is thus renewed. The galena, together with the hydrate of iron and what zinc has not been dealt with, is smelted and the silver and lead saved together in the ordinary way. The process appears to be admirable, as it affords a smelting mixture which is very easily treated and the original solution of ferric chloride is continually renewed.

Galena, or sulphide of lead, is the principal ore of lead, and the permanent ore in depth; but at the outcrops of lodes several other minerals, mentioned in the table, which are products of decomposition, are found. These are the oxidised ores, such as carbonate, sulphate, phosphate, arseniate, and, more rarely, molybdate and chromate of lead. The combinations of lead

with chlorine (except as pyromorphite) are very rare, and so also is the oxide.

Although carbonate, arseniate, and phosphate of lead are of very frequent occurrence in galena lodes, they are seldom sufficiently abundant to be considered as regular ores, except in the upper workings before the water level is reached, below which galena is to be expected as the permanent ore.

As galena is often accompanied by iron and copper pyrites, there is generally a gossan on the back of the lode in which crystals of carbonate of lead, mostly as white tables or needles, are found in the vughs and crevices.

Carbonate of Lead.—Carbonate of lead is not only found crystallised, but also in earthy masses of a yellowish or ochreous colour, and may be readily distinguished by its weight. When occurring in this form, it is usually mixed with earthy substances and oxide of iron, but if a specimen is broken carbonate of lead in a pure state will generally be found in the centre, and be recognised by its bright vitreous or adamantine lustre.

Lead-antimony Ores.—There are several compounds of lead with antimony, but they are never sufficiently plentiful to be considered as ores. One of these, jamesonite, contains small proportions of iron, copper, zinc, and bismuth. It occurs in grey fibrous masses or small prisms, and is found in Cornwall associated with quartz and bournonite. Another of these compounds, zinkenite, resembles stibnite and bournonite and occurs in an antimony mine in the Hartz.

Bournonite.—Bournonite, which is spoken of in the chapter on Copper Ores, is a compound of lead, copper, and antimony. It occasionally forms mineral deposits by itself, as, for instance, in Columbia, South America.

Lead Lodes.—The ores most commonly found associated with galena in lodes are zincblende, iron and copper pyrites, and arsenical iron or mispickel.

The matrix or vein stuff generally associated with lead is either quartz, fluor spar, or barytes.

Lead ores mostly occur in lodes, while copper occurs most frequently in contact veins; but lead also occurs in contact veins, and, more rarely, in masses in sedimentary deposits, especially limestone.

The best illustration of regular lodes is to be found in the lead and silver veins of the Hartz, Saxony, and Bohemia, which have an extremely regular structure. A plan of these lodes shows the veins and cross-veins belonging to different systems of fracture and filling, arranged with the regularity of a mosaic,

and in the vein itself the ores and their accompanying gangue are arranged with such order and regularity from the walls to the centre, that the name of "ribbon veins" or "banded veins" has been applied to them. As a rule, the points of the crystals are turned towards the interior of the fissure, and in consequence they are sometimes called "combed veins." The adjoining sketch represents the section of a vein at Przibram, Bohemia, the different numbers referring to the different bands of ore.

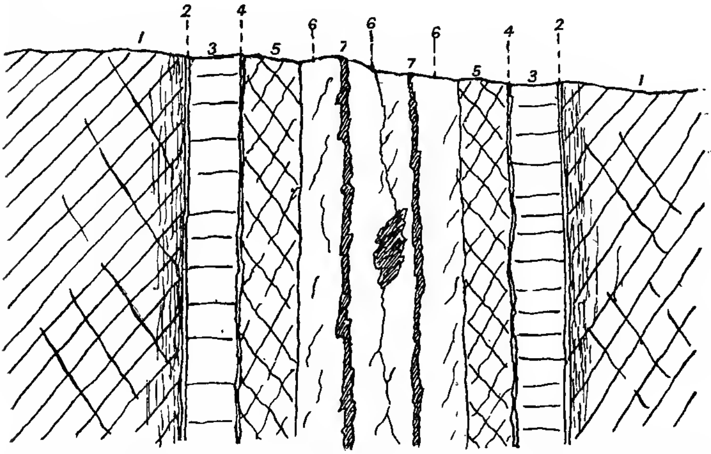


Fig. 40.—Section.—1, Casing or country rock; 2, Flucan; 3, Quartz; 4, Iron pyrites; 5, Calcite; 6, Quartz and barytes; 7, Zinc-blende and galena.

Lodes of this sort afford evidence of very slow deposition from waters carrying the mineral matters in solution. This has allowed the ores and minerals to crystallise beautifully, sections of the veins showing plainly the order in which the various minerals were deposited, the oldest deposits coating the walls of the lodes, the youngest being found at the centre.

This banded structure is almost peculiar to lead and silver lodes; but some deposits of copper, iron, manganese, zinc, &c., are also found in "combed veins." As already stated, lead ores also at times occur as "contact deposits," most of the silver lead mines worked in the centre of France, on the boundaries of the granitic region called the central plateau, occurring under these conditions.

In the neighbourhood of Pontgibaud the country is composed of granite, mica schists, and gneiss, and the lodes are in granite. Numerous dykes of porphyry crop out at the surface, and the vein stuff is a kind of granite differing but little from the country rock and much decomposed at the surface, involving a heavy expense in timbering. The ore is disseminated through the granitic matrix in veins, strings, or irregular masses, or in fine grains.

The galena is generally accompanied by a little zincblende and pyrites, while grey copper and barytes occasionally occur in some of these contact veins, but are replaced by quartz in depth; others contain fluor spar.

Shoots.—The ore forms chimneys or shoots rarely more than 150 feet to 250 feet in length, but permanent in depth.

Other similar deposits occur in the granitic chain of Forez; most of them in gneiss, but some in granite. One of these in granite is formed of two small leaders, which occasionally join together. The associated minerals are the same—viz., blende and pyrites; the vein stuff is quartz with a little heavy spar, and the ore occurs under nearly the same conditions as those just described in irregular pockets or shoots.

In the same region other contact deposits occur in granite, mountain limestone, or sandstone, sometimes at the contact of porphyry, and have about the same composition as those mentioned above.

CHAPTER XII.

QUICKSILVER OR MERCURY.

Cinnabar or sulphide of mercury is the only regular and valuable ore of this metal. It is of a bright red to brownish-black colour, is always red in powder, and affords fumes of quicksilver when heated with soda on charcoal. Native mercury and amalgam also occur, and grey copper or tetrahedrite sometimes contains this metal.

Tests for Cinnabar.—Cinnabar is very easily scratched with a knife, affording a deep red streak, and before the blowpipe it volatilises, giving off a strong odour of burning sulphur; mixed with dry carbonate of soda and heated over a candle flame, in an iron spoon, it gives off vapour of mercury, which may be condensed on a gold coin held half-an-inch above the

mixture. The surface of the coin appears whitish at first, but when rubbed between the fingers becomes brilliantly amalgamated; with care this test easily detects 1 per cent. of cinnabar in an ore; the mercury is removed from the gold coin by gentle heating. Blowpipe tests distinguish cinnabar at once from red oxide of iron, and all other red minerals.

Native Mercury in a pure state is rarely found, but occurs disseminated in liquid globules in cavities in the cinnabar-bearing rocks, especially at or near the surface. It is easily recognised, and a rock suspected to contain metallic mercury may be tested by simply heating it as described above, but without the addition of carbonate of soda.

Cinnabar Deposits.—Cinnabar occurs in the Palatinate as lodes, and impregnations which have penetrated from the lodes, in strata of Carboniferous age, and in the eruptive rocks which traverse them—viz., porphyry, melaphyre, and amygdaloid. These deposits are nearly exhausted.

At Idria, Austria, cinnabar is found in impregnated beds and stockworks in bituminous shales, dolomitic sandstones, and limestone breccias of Triassic age, dipping 30° to 40°, and covered by Carboniferous sandstones and shales in a reversed position. This deposit has been worked for nearly 400 years, and is said to become richer as the depth increases.

The quicksilver deposits at Almaden, in Spain, have a far remote history, for in the time of Pliny 10,000 lbs. were sent annually to Rome from these mines. They occur in upper Silurian slates, sometimes interstratified with beds of limestone; but the ordinary slates themselves, which are much contorted, rarely contain cinnabar. The enclosing rock usually consists of black carbonaceous slates and quartzites alternating with schists and fine-grained sandstones.

These bed-like deposits incline, near the surface, at an angle of about 65°, and then dip almost vertically. They consist principally of quartz with either granular or compact cinnabar, which permeates the mass generally, and is concentrated in pockets and bunches; while the clefts and cavities by which the deposit is traversed often contain native mercury. Veins of cinnabar occur in the neighbourhood and also eruptive rocks, diorites, with which the deposit seems to have some relation, showing that the beds are impregnations, probably originating from the veins.

The quicksilver-bearing belt of California extends along the coast range for a distance of about 300 miles. The description of some of the deposits would be highly interesting and instruc-

tive, but space will only allow of a rapid glance at their general mode of occurrence as described in a report by M. G. Rolland (*Ann. des Mines*).

"These deposits are generally impregnations in the Cretaceous and Tertiary formations; they seem to be richer when the beds are more schistose and transmuted; they are more or less closely in relation with serpentines which are themselves sometimes impregnated. The cinnabar is mostly found in talcose and clay schists, often decomposed and impregnated with oxide of iron, sometimes in quartzose schists, in sandstones, more rarely in limestone rocks, limestone breccias, &c. Native mercury is found in some magnesian rocks near the surface. There are no defined fissures nor veins proper. The cinnabar with quartz, pyrites, and bituminous substances is sometimes disseminated in the rock in fine particles and spots, sometimes forms certain kinds of stockworks or reticulated veins and nests. The parts thus impregnated congregate and form rich zones, the size of which occasionally reach 80 fathoms, and the percentage 35 per cent., and flat-like veins or lenticular deposits, the strike and dip of which agree with those of the schists of the country generally. These rich zones without defined limits gradually merge into poor stuff containing half a unit per cent., or mere traces, and are of no value."

Sulphur Bank, one of the principal mines, was originally worked as a sulphur deposit. Sulphur in workable quantities is known to exist in some volcanic countries, and volcanic rocks are abundant at the Californian cinnabar mines.

The author previously quoted remarks that a trachytic lava, probably of post-Eocene age (Tertiary) is quarried for the cinnabar with which it is impregnated, and adds:—"Some geyserites (siliceous deposits from geysers) and some modern deposits, calcareous or siliceous, of concretionary form, and produced by old hydrothermal springs, are coloured by cinnabar. Lastly, there are actually geysers and hot springs which deposit cinnabar."

He quotes the Steamboat Springs, Nevada; the Iceland Geyser; the Ohaeawai Springs in New Zealand; and the Solfatara of Puzzuoli, near Naples. At the Steamboat Springs the percentage, though very low, is not so low as to be neglected, and a deposit of cinnabar which is being worked, and is, at the same time, in process of formation, can be seen there.

In a very interesting paper published in the *Transactions of the Institution of Mining and Metallurgy*, vol. iv., Mr. James Mactear says, in speaking of the Mexican deposits, "It would seem

as if the general line of the Californian deposits was continued through the Mexican mountain ranges, but there seems also to be another line of deposits extending in a direction north-east and south-west." He also says, "It is found that there are very considerable differences to be met with both as regards the character of the quicksilver deposits themselves and the nature of the associated rocks; but it is abundantly clear that the deposits have in all cases resulted from the action of mineral springs. There can scarcely be a doubt that these were hot springs similar in character to those now in action in California and New Zealand."

In Queensland, at Kilkivan, near Gympie, cinnabar occurs in lodes of calcite, and sometimes of calcite and quartz. These have not been worked yet on an industrial scale, so that little can be said of their extent in depth; but it may be concluded from the few known occurrences in the world that quicksilver is, of all ores, the most likely to impregnate large belts of country.

Cinnabar has been found in alluvial deposits in New South Wales, and also at Waipori, in New Zealand; in the latter place it occurs as rolled fragments in the wash.

One of the most interesting localities in New South Wales is on the Cudgegong River, near Rylstone, and has been described by the late Mr. C. S. Wilkinson as follows :—"Perhaps the most important feature connected with the occurrence of the ore is that the solid cinnabar is sometimes seen to gradually merge into, or impregnate, the clay or drift of the deposit in which it is found. This is, then, direct evidence that it has not been drifted by running water, like the water-worn pebbles and other material forming the old tertiary lead; but that it has probably been derived from thermal waters which issued from the underlying Devonian rocks, and permeated the tertiary deposit."

Deposits are traced by the occurrence of red grains of cinnabar in alluvia; these cannot be confounded with red hæmatite nor red oxide of copper if the blowpipe is used. As to the appearance of the ore, it is very variable, and it will be useful to quote the varieties of colour it assumes at Idria, and the names by which the different classes are distinguished by the miners there.

Stahlerz (steel ore) contains 75 per cent. of mercury, and occurs in a compact or fine granular form.

Lebererz (liver ore) is compact and lustrous, usually forming nests in the stahlerz.

Ziegelerz (brick ore) is sandy, granular, and of a bright red colour.

In all the above-mentioned deposits, cinnabar is found in connection with rocks impregnated with carbonaceous or bituminous matter, and in every case where deposits have been worked upon an extensive scale, there is evidence of great volcanic disturbances, which have apparently been the cause of the deposition during the solfatara stage of eruption.

Annual Produce of Mercury.—The annual output of mercury for the world is stated to be about 100,000 flasks of 76·5 lbs. each, and Spain produces about one-half of this.

Payable Grades.—To give some idea of the grade of ore that is payable, it may be mentioned that the New Almaden mine paid $257,478 in dividends on mining 22,615 tons of ore yielding 2·02 per cent., and $53,641 on mining 25,584 tons of ore yielding 1·22 per cent. of mercury, but, of course, the conditions vary in every different locality. The average price of quicksilver is about £6, 10s. per flask.

TABLE OF MERCURY ORES.

Mineral.	Composition.	Hardness.	Specific Gravity.	Streak.	Remarks.
Cinnabar, .	Sulphide of Mercury	2½	8	Red	Volatile when heated and yields mercury with carbonate of soda.
Quicksilver, .	Native	...	13·6	...	Volatile when heated.

CHAPTER XIII.

COPPER.

THE minerals and ores of copper are generally easy to recognise in consequence of their very conspicuous colours; they are also the most commonly known, both for the above reason and also on account of their frequent occurrence.

General Characters of Copper Ores.—All copper minerals, with carbonate of soda on charcoal, yield before the blowpipe a

bead of copper, which sometimes contains iron. They impart a green colour to the flame, and colour the borax bead green. In nitric acid they give a green solution, which becomes azure blue when ammonia is added; and metallic copper will be deposited on iron in a nitric acid solution.

Classification of Copper Ores.—They may be subdivided into those ores in which copper is in combination with sulphur, arsenic, or antimony alone; and those which are oxidised; these are classified in the two following tables:—

TABLE OF UNOXIDISED COPPER ORES.

Mineral.	Copper combined with	Copper per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Native copper,	...	...	2·5–3	8·4–8·9	Shining	Metallic and ductile.
Chalcopyrite, .	S, Fe	34	3·5–4	4	Greenish-black	Yellow, often iridescent (peacock ore).
Bornite or erubescite,	S, Fe	55	3	5	Black	Purple, crystals rare.
Tetrahedrite or grey copper,	S, Sb, As, Zn, Fe, Ag, Hg	35–40	3–4	5	Dark brown or black	Streak dark red; when rich in zinc mineral; grey.
Tennantite, .	S, As, Fe	51	4	4·5	Reddish-grey	Crystallised or massive.
Enargite, .	S, As, Sb, Fe	47	3	4·4	Black	Rarely crystallised.
Covellite, .	S	66	1·5–2	4	Black	Indigo blue.
Redruthite or copper glance,	S	79	2·5–3	5·8	Black	Very easily sectile.
Bournonite, .	Sb, S, Pb 41 %	13	2·5–3	5·8	Dark-grey	Shining conchoidal fracture
Arsenides of copper,	As	70–88	3·4	7–8	...	Before blowpipe yields blackish-grey malleable bead.
Stannine, .	S, Sn	24–30	4	4·3–4·5	Black	Takes silvery polish; tarnishes on exposure.

S, Sulphur; *Sb*, Antimony; *As*, Arsenic; *Fe*, Iron; *Zn*, Zinc; *Pb*, Lead; *Ag*, Silver; *Hg*, Mercury; *Sn*, Tin.

TABLE OF OXIDISED COPPER ORES.

Minerals.	Composition.	Copper per cent.	Hardness.	Specific Gravity.	Colour and Streak.	Remarks.
Melaconite, .	Oxide	80	3	6·2	Black	Usually earthy, soiling the fingers.
Cuprite, .	Oxide	88	3·5–4	6	Cochineal-red, streak brown	Often covered with malachite.
Chalcanthite,	Sulphate,	25	2·5	2·2	Blue	Crusts and prisms; soluble in water.
Azurite, .	Carbonate	55	3·5-4	3·8	Azureblue	Often in radiated crystallised concretions.
Malachite, .	Carbonate	57·5	3·5-4	4	Emerald green	Often mammillated and fibrous.
Libethenite, .	Phosphate	53	4	3·8	Green, streak greenish-yellow	Small crystals, surface dark.
Atacamite, .	Oxychloride	44·5	3-3·5	3·7	Dark olive green	Crystallised, fibrous, or granular.
Arseniates of copper,	...	50-60	3-4	3·5-4·2	Green	Sometimes crystallised.
Chrysocolla, .	Silicate	37	2-3	2·2	Green or bluish	Crusts and coatings.
Dioptase, .	Silicate	40	5	3·3	Emerald green	Crystallised; rare.

Native copper, in the celebrated copper region of Lake Superior, in North America, forms the regular ore of the mines. It occurs in grains of all sizes, and occasionally in huge masses of over a hundred tons in weight, in beds of conglomerate, alternating with trappean rock.

Copper Ores.—Copper pyrites or chalcopyrite is the most common ore in nearly all the copper deposits of the world, while blue and green carbonates, in crystals, concretions, or impregnations are the surface ores formed by the decomposition of copper pyrites and other ores of copper.

Copper also occurs combined with sulphur as bornite or

purple copper ore; redruthite, or copper glance; and tetrahedrite or grey copper. These generally accompany copper pyrites, being more or less abundant, and sometimes become the principal ore in the lode, as, for instance, purple copper in Tuscany, grey copper in Germany, and copper glance in Siberia and New Zealand.

The carbonates are accompanied near the surface by other oxidised ores, such as cuprite or red oxide of copper, melaconite or black oxide of copper, as well as the phosphates, arseniates, silicates, and oxychloride. Of these, cuprite and melaconite are the most important, and sometimes form the permanent ore of mines to a considerable depth.

These oxidised surface ores are usually mixed with hydrous oxide of iron or gossan forming the cap of the lode.

To understand the occurrence of gossan in the upper parts of a lode, it must be borne in mind that copper pyrites and purple ore are sulphides of copper and iron The surface waters which percolate through the rocks remove the sulphur and copper as sulphate of copper, leaving the iron in the form of a more or less spongy and honey-combed mass, which is called "gossan." It is consequently easy to anticipate from the nature of a gossan if the ore lying below is likely to be a rich compact copper ore, or whether it is mostly composed of iron pyrites carrying little or no copper. In the first instance the large percentage of copper which has been removed must have left the iron in a very porous condition; while in the latter the gossan will generally be more compact.

Copper pyrites is not generally found pure immediately below the gossan, but a richer ore, commonly called "black ore," which has no special mineralogical name, is first met with. It is black and earthy, like manganese or black copper ore, but, if broken, nests of copper pyrites will generally be found in the centre, and the ore passes from black to yellow through intermediate shades of bronze.

What is called "peacock ore" is only copper pyrites coated with oxide and exhibiting iridescent colours. By leaving a piece of clean yellow copper pyrites in water for some time it will become coated in this way.

The easy decomposition of copper ore under the influences of the atmosphere explains why the waters at some copper mines are quite unfit to drink. It is well known that tools abandoned for a time in old workings become covered with a coating of metallic copper, as if they had been left in a bath of sulphate of copper.

Native copper in copper lodes is also a product of decomposition of sulphides, and is often found as plates, when deposited on the side of a cavity or fissure; or as ramified crystals, when deposited in a soft clay.

Tests for Copper Ores.—The various copper minerals enumerated in the tables may be distinguished in the following manner, a bead of copper having first been obtained from the specimen before the blowpipe:—

The Bead of Copper contains Iron, and is therefore attracted by the Magnet.

a. Colour of mineral, gold-yellow; sometimes iridescent on surface. **Copper pyrites.**

b. Colour, black on surface; fracture shows the colour of copper pyrites in the interior. **Black ore.**

c. Colour, violet or between copper-red and reddish-brown. **Erubescite.**

d. Colour, steel or lead-grey, or iron-black.

Grey Copper, before the blowpipe, yields abundant fumes of antimony. Sulphur is always present, and arsenic is sometimes detected.

Tennantite.—Odour of garlic due to arsenic is prominent, and sulphur also present.

The Bead of Copper is not attracted by the Magnet.

1. *Lustre metallic, semi-metallic, or resinous.*

a. Colour, indigo blue; lustre, not quite metallic; more nearly resinous when crystallised, and resinous or dull when massive. **Covellite or indigo copper.**

b. Colour, iron or steel-grey; lustre, metallic.

Redruthite, before blowpipe, is very fusible, and yields a smell of sulphur.

Bournonite is easily fusible, and emits white fumes due to antimony.

Melaconite is infusible.

2. *Lustre non-metallic.*

a. Colour, black; earthy, soils the fingers. **Melaconite.**

b. Colour, cochineal red; dust, brown-red. **Cuprite.**

c. Colour, blue; soluble in water. **Chalcanthite.**

d. Colour, blue or green; insoluble in water.

Azurite, which is blue, and **malachite**, green, are fusible, and their powder is soluble in acids with effervescence.

Libethenite, Atacamite, and Arseniate of Copper are green, fusible, and soluble in acids without effervescence. Atacamite colours the flame, near the substance, blue, and arseniates of copper emit smell of garlic before the blowpipe.

Chrysocolla and Dioptase are green, and infusible.

Chalcopyrite, or copper pyrites, is only to be compared with iron pyrites, which it somewhat closely resembles. It will not be mistaken for gold, although it has the colour of that metal; nor for stannine, purple copper ore, or variegated copper. Stannine, although sometimes yellowish, has a greenish hue, and copper pyrites is distinguished from iron pyrites by being easily cut by a knife, and crushed to powder with a hammer; while iron pyrites is much harder, scratches glass easily, and strikes fire with steel. Iron pyrites, in consequence of surface decomposition, sometimes exhibits the variegated colours of the so-called peacock ore, and is likely to be mistaken for it in this state if not tested with the knife. It is always advisable to examine the colour in a freshly-broken specimen, when the yellow colour of copper pyrites is characteristic.

Grey copper, including *tennantite* and *enargite* (which are only varieties) are not so easy to distinguish, their steel grey colour being similar to that of many other minerals.

When crystallised they sometimes resemble zincblende, but this last mineral gives a white dust when scratched, and is infusible. More complicated crystals are liable to be confounded, at first glance, with hæmatite or specular iron, arsenical cobalt, and grey cobalt, both of which latter contain arsenic, and with silver glance or argentite.

When massive, the analogies with other minerals are still more numerous. Grey copper and its varieties may be mistaken for magnetic iron, chrome iron, mispickel, gersdorffite, stibnite, the cobalt ores mentioned above, argentite, or redruthite.

The iron and chrome ores are much harder than grey copper, and are moreover infusible. The nickel and cobalt ores are very heavy, which is sufficient to distinguish them; besides which, they will be recognised by means of the borax bead. Mispickel is silver white, and when struck with a hammer smells of garlic; while the light-coloured varieties of grey copper, which might be mistaken for it, do not contain arsenic. Stibnite is fusible when brought near the flame of a candle, and volatile when heated before the blowpipe. Sulphides of copper and argentite are sectile and malleable, while grey copper is brittle; besides which, the sulphides smell of sulphur when heated before the blowpipe, while grey copper gives white fumes due to antimony.

Bournonite, when massive, is also likely to be mistaken for grey copper, and a reduction on charcoal with soda will be necessary to distinguish them, when a bead of lead and copper will be obtained from bournonite. When the prismatic crystals

of bournonite are longitudinally striated, they resemble stibnite and the prismatic manganese oxides, but the manganese ores are infusible, and stibnite volatilises entirely before the blowpipe. A ready test for bournonite is its fracture, which is perfectly conchoidal and shining.

The ores of copper, which do not possess a metallic lustre, will be easily distinguished from other minerals of similar appearance by the following characters :—

Cuprite, when crystallised, might be mistaken for zincblende or other minerals of the same form, such as magnetite. It will, however, be readily distinguished by its red streak. When lamellar it might be mistaken for red silver; but this mineral gives abundant antimony fumes before the blowpipe. Cinnabar, which is also red, will entirely volatilise before the blowpipe; besides which, the difference in specific gravity is appreciable, that of cinnabar being 8, and of cuprite 6. Cuprite will also give the green flame due to copper.

Black Oxide of Copper will be distinguished from black earthy manganese and cobalt wad by the borax bead in the oxidising flame, which is violet with manganese, and deep blue when cobalt is present; while copper alone gives a bead which is green when hot, and pale blue or greenish-blue when cold.

Azurite will be distinguished from lapis lazuli and vivianite, when earthy, by being soluble in acids with effervescence. When crystallised, azurite does not resemble any other mineral.

Malachite will also be distinguished from other green minerals, which are numerous, by being soluble with effervescence in acids. The minerals likely to be mistaken for malachite are some arseniates and phosphates of copper and atacamite amongst the copper ores and, amongst other minerals, pyromorphite and copper uranite. These minerals are all green, but of different hues.

Pyromorphite will be readily distinguished from copper ores by its high specific gravity; besides which it is not always green, but often yellowish-green, yellow, or brown. Copper uranite, which crystallises in laminæ, exhibits on the larger faces a pearly lustre, and fuses before the blowpipe to a blackish mass. The arseniates and phosphates of copper are soluble in ammonia, and the arseniates give before the blowpipe the characteristic smell of garlic. Atacamite gives the blue flame characteristic of chloride of copper when brought near the flame of a candle, it not being necessary to previously moisten the mineral with acid.

Copper Ore Deposits.—Copper occurs in various kinds of

rock in lodes of very different age. It is, of course, difficult to determine the age of a lode which occurs in crystalline schists or sedimentary strata, unless they are overlain by beds which are not traversed by the lode and of which the age is known; but some copper deposits have been formed in very recent times. Where copper ore occurs in beds or impregnations it does not follow that the ore has in all cases been deposited at the same time as the bed in which it is found. In Germany, however, near Mansfeld, there is a typical instance which leaves little doubt that the ore was formed at the time of deposition of the strata or during the Permian period, the formation being known as the "copper slate." The average composition of the ore is constant over a large area, and the rock contains from 2 to 3 per cent. of copper with a small proportion of silver and gold which make it payable to work with cheap labour and fuel.

Copper ores occur in true fissure lodes, in crystalline schists and in rocks of all ages, and are also common in eruptive rocks, especially porphyry, melaphyre, and serpentine; and in sedimentary strata from the Cambrian period to Tertiary times.

Copper very frequently occurs in contact deposits; where this is the case it has been segregated from the eruptive rocks, either diorite, gabbro, or serpentine, and lies either at the junction of one of these rocks with sedimentary strata or at the junction of two eruptive rocks of different ages. A well-known instance of a copper-bearing contact deposit is that of Monte Catini, in Tuscany, where the rock which carries the copper is serpentine. The ore in deposits of this sort occurs in rounded irregular masses, and the features of the lodes are of a very variable character.

It should be borne in mind, especially when exploring a new country, that copper is frequently associated with rocks of a dark colour, which are very often green; but it must not be supposed that the colour is imparted by copper, for it is generally due either to some other metal, such as iron, or to the presence of a green non-metallic mineral, such as chlorite.

Serpentines and hornblendic rocks are often associated with copper ores, but green serpentines owe their colour to iron, nickel, or chromium; and if copper is found disseminated through some of them, it is the exception, and not the rule, unless in the immediate vicinity of ore deposits. On the contrary, iron and chromium are found in all serpentines, and nickel frequently occurs.

Hornblendic rocks are green, grey, or black, according as

actinolite (which is green) or common hornblende (which is black) occur in them. Actinolite is of frequent occurrence in some schists, and black hornblende in diorites, and other dark coloured rocks which are associated with copper ores.

Other green minerals enter into the composition of some rocks, especially gabbros, so it may be clearly understood that the green colour of rocks is seldom due to the presence of copper; and although green rocks are frequently associated with copper ores, they are not always to be looked on as indications of the occurrence of deposits of this metal.

Near Wallaroo, the most reputed mines of South Australia, hornblende is of frequent occurrence in the rocks of the country, which are mica and talc schists, the nearest ridge being composed of syenite.

In New Caledonia the copper region occupies both flanks of a mica schist range in which hornblende is very common, and occurs associated with garnets, chlorite, and white and green micas; and through these rocks serpentine protrudes at places, especially in the vicinity of the copper deposits. The main deposit which has been worked consisted of several parallel shoots or pipes of ore enveloped in foldings of the schists.

Serpentine occurs in several parts of Australia where copper also is known, and also in New Zealand; but, although serpentine is frequently associated with metals, and especially copper, it does not follow that it is always accompanied by such deposits; in fact the serpentines of the Lizard in Cornwall, although in a copper-bearing district, are devoid of copper ores themselves; besides which, although contact deposits are generally numerous where they occur, they are seldom of great importance, and are very irregular.

Australia is wonderfully rich in copper. It is sufficient to mention Wallaroo in South Australia, Peak Downs and Cloncurry in Queensland, Cobar and Nymagee in New South Wales, and Mount Lyell in Tasmania.

Copper ores generally occur with quartz as a gangue; but occasionally some other minerals, such as fluorspar, barytes, and calcite, are found in association with them.

The ores of copper, or indeed of any metal, are always associated with other ores in greater or less quantities; but those veins in which there is the least variety are generally the most valuable, since they are more easily concentrated, and their metallurgical treatment is more simple.

Copper ores, especially copper pyrites, grey copper, and melaconite occasionally contain silver and gold. At Lake Superior

native copper often contains nuclei of pure silver enclosed in the mass of copper without being alloyed with it.

Iron pyrites sometimes contains copper at the rate of a few units per cent., as in Cornwall and at Huelva in Spain, where some extensive deposits of pyrites are worked for sulphuric acid and yield 1 or 2 per cent. of copper, with a very small proportion of silver and gold, but still sufficient to give a reasonable profit. Poor copper ores or cupriferous tailings, when in sufficient quantities and when suitable materials are at hand, can be worked very cheaply by one of the many wet processes known.

Yellow copper ore is seldom pure copper pyrites, but is generally mixed with more or less iron pyrites; so that an assay is always necessary to determine the value of an ore. It is often the case that a picked specimen of apparently pure chalcopyrite mixed with a small quantity of quartz will yield about 25 per cent. of copper, or even less, instead of over 33 per cent., which it should do theoretically. This low return is not due to the presence of quartz alone, but to an admixture of iron pyrites; and it is seldom the case that a concentrated pyritous ore yields more than 15 per cent. of copper on an average in a large consignment.

CHAPTER XIV.

Tin—Titanium—Tungsten—Molybdenum.

TIN.

Cassiterite or oxide of tin is the only ore of this metal, although another mineral, **Stannine**, containing tin, copper, and sulphur is known. Stannine is not sufficiently abundant, however, to be of much importance, and, although it has been found in lodes of some size in Cornwall, it is sold as an ore of copper and not of tin.

Tinstone stands nearly by itself in its mode of occurrence and formation, as a type of a strongly marked class of deposits. It is always associated with granitic rocks, quartz-porphyries, or gneiss, all of which are of analogous composition, being rich in silica, which crystallises as quartz, and being called in consequence "acidic" rocks. Tin lodes are nearly all of great antiquity and

occur only in those of the above-named rocks which are characterised by the presence of white mica. It is only in two or three places in the world, notably Tuscany and Elba, that granites of this type have been erupted during recent times, and they contain tin in small quantity, as well as some of the minerals usually associated with it, such as tourmaline, lithia mica, and emerald.

Although this fact is of no immediate practical value, it is important, because it shows that there really are laws which govern the distribution of minerals, although these are sometimes very obscure; but by constant observation it is certain that, amongst discoveries of merely scientific interest, laws capable of practical application will occasionally be found.

Tinstone is always associated with quartz and rarely occurs in green rocks, unless their colour be due to chlorite; nor in dark coloured rocks, except where stained red by the decomposition of ferruginous minerals; neither is it found in limestone.

Those granites which are characterised by abundance of white mica have, with good reason, been termed "tin granites," and a coarse-grained rock composed of granular quartz mixed with white mica, and called "greisen," occurs in all the tin fields of the world—*e.g.*, Cornwall, Germany, and Australia.

The minerals most commonly associated with tin—viz., topaz, mica, tourmaline, fluorspar, apatite, and other rarer minerals containing fluorine—seem to show that it was originally contained in the granite as fluoride of tin, and that the associated minerals have been formed at its expense. It is an established fact in the genesis of minerals that fluorine is always accompanied by silicon and boron; it is therefore natural to find silicates containing boric acid, such as tourmaline and axinite, in association with tin. Other minerals which frequently accompany this metal are wolfram, molybdenite, mispickel, garnet, beryl, &c.

Tin appears to have been brought to the surface disseminated through the granite in which it occurs; and has subsequently been concentrated in all the cracks and joints of the rock, forming in many cases a perfect network of veins known as stockworks; the best known instance of this class of deposit being in the Erzgebirge Range in Saxony. At Zinnwald, the tinstone is concentrated in a number of curious concentric zones, which, for a thickness of about 1 foot, are impregnated with tin, so that the whole of the rock has to be removed for the extraction of the ore. The rocks constituting these zones are greisen impregnated with tinstone and wolfram, and they have been

frequently displaced by vertical and inclined fissures which reach the surface.

The tinstone in these beds appears to have been formed contemporaneously with the greisen in which it occurs, and the greisen itself is probably a granite altered *in situ*, topaz being formed at the expense of aluminous silicates.

The stockwork at Geyer consists of a mass of granite in mica schists, traversed by numerous tin lodes, from which the ores and other minerals have penetrated into the joints of the granite. The same veins extend into the surrounding mica schist, but there they appear to contain less ore. Considerable confusion exists in the use of the term "stockwork," and so the foregoing instances are given in illustration of this class of deposit, but in the chapter on "Irregular Deposits" the different characters have already been described.

The Altenberg deposit consists of a rock called "stockwork porphyry," or "zwitter rock," and is tin-bearing throughout; but the ore is so finely disseminated as to be hardly perceptible, and in such small quantities that often one-third to one-half per cent. only can be produced from it. The rock is a fine-grained greisen, and the term of porphyry is very inappropriate. It merges gradually into the surrounding country, which is composed of granite, chloritic granite, porphyry, and quartz porphyry, no clear line of demarcation existing. The rock is dark coloured, sometimes almost black, and consists of quartz, mica, chlorite, tinstone, &c., and pyrites is disseminated through it in minute particles; but the quartz alone can be distinctly recognised; it frequently occurs as grains without crystalline structure. Molybdenite, bismuth glance, copper pyrites, iron pyrites, fluorspar, topaz, &c., also occur, and the rock is traversed by numerous quartz veins.

Tin ore often occurs disseminated through a rock in which the boundaries of the stanniferous deposit are not well marked, and two classes of these deposits may be distinguished.

1st. Disseminations or impregnations formed at the same time as the rocks in which they occur.

2nd. Impregnations in which the ore has been introduced by the mineral waters, which charged the lodes, traversing the rocks.

This last class of impregnations is well illustrated by the stanniferous capels which adjoin many tin-bearing lodes, and are very variable as regards their width. Tin floors are also illustrations of their disposition.

The ore is found in places as crystals and crystalline patches;

in others, the particles are so finely divided as to be invisible to the naked eye; and in others, again, it occurs as minute spherical aggregations.

Tinstone also occurs largely in lodes, and these are generally the oldest lodes of the district; but in some cases in Cornwall copper lodes have been known to change to tin in depth, so that this law cannot be looked upon as infallible.

Tests for Cassiterite.—Cassiterite or tinstone is a mineral which should be very readily recognised, and yet there is probably no other ore for which so many different minerals are mistaken. Its specific gravity alone, between 6·8 and 7·1 should be sufficient to distinguish it from the greater number of minerals which resemble it more or less closely.

Rutile most closely resembles tinstone in crystalline form and external appearance, but it is much lighter; specific gravity, 4·2. The streak or powder of rutile is brown-yellow, while that of tinstone is from light grey to brown.

Wolfram has nearly the same specific gravity as tinstone, and so will be associated with it in the tin dish, but the streak of wolfram is black or reddish-black, and the hardness about that of glass, while tinstone is much harder.

Zincblende, commonly called "black jack," is not heavier than rutile, specific gravity 4·3, and is not so hard as either rutile or tinstone, being scratched by a knife. Its streak is yellowish-white to brown, approaching that of rutile, and its lustre and external appearance are much like tinstone. When it contains much iron and is black, and especially when found in alluvial beds, it resembles tinstone, but will be easily separated from it in the tin dish, or recognised by blowpipe tests.

Many other minerals are at times mistaken for tinstone, but they can be very readily distinguished.

Chromite has about the hardness of glass or wolfram, but is not so heavy as that mineral. In the tin dish it would be found with rutile, &c., its specific gravity being 4·5; so that it would be readily separated from tinstone. It also affords a green bead with borax. Magnetite, titanic iron, and specular iron have all about the same specific gravity, and will, as well as chromite, yield a magnetic bead when heated on charcoal with soda; magnetite and titanic iron are themselves magnetic.

The *gems* which are sometimes taken for tinstone are all harder than orthoclase, and, with the exception of garnet, will not be scratched by tinstone itself. The lightest of these are spinel, specific gravity 3·5, and tourmaline, specific gravity 3·2; and it is only the black varieties which are liable to be mistaken

for tinstone. Tourmaline which crystallises in prisms; and garnet in rhombic dodecahedrons, are both fusible before the blowpipe; but, apart from negative tests of this sort, tinstone may be readily reduced on charcoal, with cyanide of potassium, to a metallic state. The tin thus obtained will not give any white or coloured coating on charcoal like zinc, lead, antimony, or bismuth; and when the fused mass and charcoal are scraped off, crushed in an agate mortar, and washed, the tin will be separated in metallic scales.

The mode of occurrence of the different minerals will also afford some guide as to their characters, except of course when they are found in alluvial deposits.

Cassiterite Deposits.—Tinstone, as already mentioned, is essentially a mineral of the acidic eruptive rocks, such as granite, quartz-porphyry, and greisen; but it also occurs in lodes traversing crystalline schists, such as gneiss, mica schist, or chlorite schist, and also in clay-slate, or "killas," but never at a greater distance than 3 miles from granite.

Wolfram also occurs in lodes, as at the East Pool mine, near Redruth; but rutile, zircon, garnet, and tourmaline mostly occur either disseminated through the rocks or crystallised in cavities. Wolfram and tourmaline are generally found in tin bearing rocks, but spinel (pleonaste), chromite, and titanic iron are generally associated with basic rocks of dark colour, such as serpentine, basalts, &c., and are, therefore, less likely to be mistaken for tinstone. Magnetite occurs in considerable masses in crystalline schists, hornblende schists, and serpentines; and is also disseminated as grains through many eruptive rocks, such as basalt; but it is chiefly associated with chlorite.

Hæmatite is found in rocks of all ages and of every description. Lastly, zincblende occurs in lodes, especially with quartz containing galena, gold, &c.

In alluvial deposits tin occurs, under the same conditions as gold, in river beds of various age, which are sometimes covered by flows of basalt. Some leads are worked under the basalt in the northern part of New South Wales, and are known as "deep leads" as well as the similar auriferous deposits; but those which can be easily drained are rapidly becoming exhausted, and the more heavily watered leads will require to be worked on a more extensive scale to be profitable.

Rolled tin ore is in some places found in boulders of considerable size, from 5 to 20 and even 38 pounds in weight; for instance, in the Butchart tin mine. This mode of occurrence is similar to that of the tin in the Straits Settlements, and

shows that some of the lodes must contain pockets of ore of large size.

When stream tin ore is derived from concretionary lodes, such as occur in Cornwall and elsewhere, it assumes a radiating fibrous appearance which makes it resemble wood, in consequence of which it is called "wood tin." Occasionally the fragment preserves the impression of a crystal of quartz on which it has been formed. When the concretionary structure is marked only by small mammillated tubercles, it is termed "toad's eye tin" or "shot hol'd tin."

When stream tin is coarse, it often preserves its crystalline structure, and crystals as much as an inch in length, in which the edges only are rounded, are not very rare.

In alluvial deposits, it may be remarked, tin ore has generally been separated from its associated sulphides and arsenides. Wolfram is the most objectionable of the impurities which are mixed with tin, as its high specific gravity renders the separation most difficult.

Tinstone assumes many different colours and shades—*e.g.*, ash-grey, light brown, pink, ruby-red, amber-yellow, dark brown, and black. Its streak, therefore, varies from white to grey.

Chemically pure stannic acid being white, those specimens which are lightest in shade will be the purest. Some specimens from the Giant's Den, New England, are pure white.

Very dark-coloured varieties generally owe their black shade to manganese or iron, which can often be detected by the blow-pipe; and, more rarely, tantalic acid is present, also giving a dark colour to the ore.

The Mount Bischoff deposit of tinstone in Tasmania occurs under circumstances which are quite exceptional.

Mount Bischoff rises nearly 3,000 feet above sea-level. Within 150 feet from the summit there is a crateriform depression of several acres in extent, the sides and bottom of which have been composed of a rich tin-bearing detritus resting on a bottom of slate. The depth of the deposit was about 30 feet, and the rich detritus was composed of the elements of the rock itself, a kind of euritic porphyry which has decomposed *in sitû.* True lodes of tin ore have been found high up on the sides of the mountain.

TITANIUM.

Titanium occurs in nature in the form of titanic oxide; but there are three minerals which have this composition, although they vary in their crystalline form.

Rutile resembles tin ore in appearance, and occurs, sometimes, under similar geological condition; but the crystals of rutile are more needle shaped or columnar, and they often penetrate crystals of quartz or felspar. In quartz reefs rutile often accompanies gold, and is sometimes associated with chlorite, as also is tin ore. It is used for preparing some enamels.

Octahedrite occurs in elongated octahedrons, sometimes so splendent as to be mistaken for diamonds; and

Brookite is found in reddish-white plates with striated surfaces, and of a bright red colour by transmitted light.

The mode of occurrence of these two minerals is frequently the same as that of rutile, and they also sometimes accompany gold. Their lustre is adamantine, and they are likely to attract the eye when found in alluvial deposits, in which they are frequently associated with the diamond.

Titanic acid is employed for making a yellow colour used in painting porcelain, and also for giving the requisite tint to artificial teeth.

TABLE OF TIN, TITANIUM, TUNGSTEN, AND MOLYBDENUM MINERALS.

Mineral.	Components.	Metal per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Cassiterite, .	Sn, O	78	6–7	7	Grey	Square prisms, twins.
Stannine, .	S, Sn, Cu	Sn 25 Cu 29	4–4½	4·5	Blackish	Generally massive.
Rutile, .	Ti, O	...	6-6½	4·3	Light-brown	Prisms.
Octahedrite, .	Do.	...	5½-6	3·9	Grey	Splendent octahedrons.
Brookite, .	Do.	...	6	4·15	White	Red striated plates.
Wolfram, .	W; O, Fe, Mn	...	5½	7–7·5	Brown-red, or blackish-brown	Adamantine, semi-metallic, black.
Scheelite, .	W, O, Ca	...	4½-5	6	White	Octahedrons and massive.
Molybdenite,	Mo, S	...	1-1½	4·5	Lead like	Marks paper like plumbago; thin laminæ flexible.
Molybden-ochre (molybdite),	Mo, O	...	...	...	...	Generally earthy; sulphur yellow.

S, Sulphur; *Cu*, Copper; *Sn*, Tin; *O*, Oxygen; *Ti*, Titanium; *W*, Tungsten; *Fe*, Iron; *Mn*, Manganese; *Ca*, Lime; *Mo*, Molybdenum.

Tungsten.

Wolfram, which is the tungstate of iron and manganese, often accompanies tin, native bismuth, and topaz, as already stated. Its specific gravity is nearly the same as tinstone, and it is in consequence very troublesome to the tin miner. Its colour is black, and it is generally found in crystals with large cleavages, or in laminæ with a semi-metallic lustre. The thin laminæ are opaque.

Wolfram is used in the preparation of some colours and enamels, and enters into the composition of some special kinds of steel; besides which tungstate of soda, which is used as a mordant and for fireproofing fabrics, is prepared from it.

Tungsten may also be used as a substitute for tin in the manufacture of purple of Cassius.

Scheelite, which is a tungstate of lime, occurs in irregular masses in a quartz lode traversing crystalline schists near the head of Lake Wakatipu in New Zealand, and also near Armidale in New South Wales. It is white, and very heavy for a white mineral, having a specific gravity of 5·9 to 6·1. It forms a blue bead with microcosmic salt in the reducing flame.

Molybdenum.

Molybdenite, or sulphide of molybdenum, occurs in New South Wales in quartz reefs containing tin and bismuth, and worked for the latter metal; it is also frequently met with as flakes in crystalline metamorphic rocks. It is usually accompanied by an earthy yellow coating of molybdic oxide, called molybdite.

Molybdenite is used for the preparation of blue carmine for colouring porcelain.

These minerals, wolfram and molybdenite, have been described here because they are frequently associated with tinstone in its natural repositories.

CHAPTER XV.

Zinc—Iron—Nickel—Cobalt—Manganese—Chromium—Uranium.

Zinc.

Tests.—It has been stated in the chapter on the use of the blowpipe that alumina moistened with nitrate of cobalt becomes blue when heated; and that under the same circumstances oxide of zinc becomes green. The ores of zinc should be distinguished by this test; but some of them do not give a clear green, but only a bluish-green colour; besides which some other oxides are also coloured green by this treatment. The best way, therefore, to ascertain the presence of zinc, is to treat the mineral on charcoal with soda, so as to reduce the zinc, which, immediately it is reduced, volatilises, and is again oxidised, forming a coating on the charcoal. This coating being heated, will assume a sulphur-yellow colour, and become white again when cool; the test, with nitrate of cobalt, can then be made on the oxide, and a green colour obtained.

When oxide of zinc is moistened with a drop of solution of shellac in spirit, it assumes a marked pink colour without being heated, whilst alumina, under the same circumstances, is a faint yellow with a shade of red. This test should be tried with the two substances in order to note the different shades of colour.

Among the zinc ores recorded in the table, the carbonates and silicates only are at all difficult to distinguish from each other.

The sulphide of zinc or zincblende, commonly called "black jack," is easily recognised if treated with hot hydrochloric acid, as it gives a smell of rotten eggs (sulphuretted hydrogen); and the same result can be obtained without heating if a small quantity of pure iron filings is added to the acid. With soda on charcoal before the blowpipe zincblende gives a hepar which, with water on a silver coin, tarnishes or blackens it. The red oxide zincite is conspicuous by its colour, and is very rare.

The carbonates and silicates are all white, or tinged with brown, and will be identified as follows :—

SCRATCHED BY CALCITE, AND VERY EASILY BY A KNIFE—Amorphous—Hydrous—Effervesces with Acid. **Zinc Bloom.**

SCRATCHES CALCITE AND EVEN FLUOR SPAR—NOT SCRATCHED VERY EASILY BY A KNIFE.

1. Effervesces with acid. **Calamine** (Smithsonite of Dana).
2. Does not effervesce; concretionary or crystallised.

a. Heated in a tube gives off water. **Galmei** or **Electric Calamine** (Calamine of Dana).

b. Does not give off water when heated. **Willemite.**

TABLE OF ZINC ORES.

Mineral.	Composition.	Percentage of Zinc.	Hardness.	Specific Gravity.	Streak.	Remarks.
Calamine, .	Anhydrous carbonate	52	5	4·4	...	Small crystals or concretionary.
Zinc bloom, .	Hydrous carbonate	56	2–2½	3·7	Shining	Amorphous.
Willemite, .	Anhydrous silicate	58·5	5½	4	...	Small crystals.
Galmei, .	Hydrous silicate	54	5	3.5	...	Electric and phosphorescent when heated—crystallised or concretionary.
Zincite, .	Oxide	80	4-4½	5·5	Orange-yellow	Red.
Zincblende, .	Sulphide	66	3½-4	4	White to reddish-brown	Ordinarily crystallised or massive.

Zinc Ores.—Zincite occurs in New Jersey, U.S.A., associated with a mineral called "franklinite," which is an oxide of iron, manganese, and zinc. The two minerals are treated as an ore of iron, the zinc being deposited at the mouth of the blast furnace as oxide, and not interfering with the production of iron.

Zincblende occurs in rocks of all ages, and accompanies ores of lead, copper, tin, silver, and gold in lodes; but it is only when a large percentage of blende is present that the ore is worth treating for zinc. In the mines where it occurs with galena, it

sometimes forms half of the metallic ore, and can be separated from lead and some copper ores mechanically, its specific gravity being very low. Deposits in which zincblende occurs by itself are so rare that an instance deserves to be mentioned. In Sweden a remarkable deposit of blende occurs in gneiss forming a belt 200 fathoms in thickness, which can be followed for a distance of nearly two miles along its strike. The enclosed deposit of zinc ore has a very varying thickness, dips at angles from 70° to 80°, and consists of a number of lenticular masses, which sometimes attain a thickness of over 12 fathoms. The blende, which is black to yellowish in colour, is occasionally accompanied by argentiferous galena, but more frequently by iron pyrites and magnetic pyrites. The other minerals found are amazon stone, hornblende, talc, chlorite, garnet, black tourmaline, and bitumen ; calc spar is rare.

Blende is frequently found with silver and gold, and is sometimes sufficiently rich in silver to be treated for that metal, as in Portugal and, again, in New South Wales at Broken Hill.

Those ores in which zinc occurs as carbonate or silicate are found in peculiar deposits in limestone, and are frequently connected with veins of zincblende. The mineral solutions which, in such rocks as slate, have deposited blende or sulphide of zinc ; when in contact with limestone, have decomposed that rock and formed cavities, in which calamine has been deposited together with the other carbonate and silicates mentioned in the table.

The appended sketch, which represents a section of the celebrated deposit of Moresnet, near Aix la Chapelle, by Mr. Eduard Fuchs, illustrates the mode of occurrence of these oxidised ores, which have been, and are being, worked in preference to the sulphides which occur in depth. The carbonates and silicates are all oxidised surface ores of zinc, as carbonates and silicates of copper are surface ores of copper.

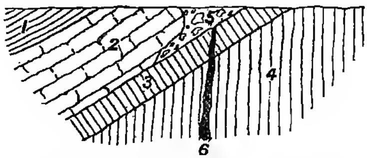


Fig. 41.—1, Coal measures; 2, mountain limestone; 3, quartz and dolomite; 4, schists and grauwacke; 5, calamine; 6, zincblende vein.

Iron.

This group includes some minerals which, in consequence of their abundance, are of great value as ores of iron ; and others

which, being rare, are of no commercial value. Those of importance as iron ores are hæmatite, goethite, limonite, magnetic iron, and siderite.

They will be easily recognised by the following characteristics:—Hæmatite, either pure and crystallised, or impure and earthy, gives a red dust when scratched, and is anhydrous. Goethite and limonite both contain water, and give a brown dust or streak. Magnetite will be recognised by being attracted by a magnet, and even sometimes, in a compact mass, acting as a magnet itself. Siderite, being a carbonate, will effervesce with acid when heated, and resembles calc spar, but is light brown instead of white.

Hæmatite occurs in lodes, but these are not the most important deposits known. In the description of stratified and irregular deposits, examples have been given of the occurrence of these ores in beds or lenticular masses in stratified rocks where they have been dehydrated by metamorphic action, having originally been deposited in the state of limonite or hydrous iron ore. Such are the well-known deposits of Cumberland and Lake Superior. As a rule, hæmatite is associated with quartz.

As deposits of only scientific interest, hæmatite is to be found in the Brazilian sandstone called itacolumite and in itabirite, where it is accompanied by the octahedral variety of hæmatite, "martite," and where diamonds are also found. It also occasionally occurs in crystalline rocks, as in granites, and has been found in some volcanic rocks of Tertiary age, as in the crater of Vesuvius.

Even when occurring as a valuable ore of iron, red hæmatite is rarely so pure as the Cumberland and Lake Superior ores, but is generally mixed with earthy matters, forming beds of great extent. Red ochre is a soft, earthy hæmatite containing fine clay, and is used in the manufacture of paints.

Goethite and Limonite, or brown hæmatite, can be considered together, the difference between them being only in the percentage of water they contain. Goethite is very rarely crystallised in definite forms, but generally occurs in fibrous concretionary or granular masses. It contains about 10 per cent. of water. Limonite is never crystallised in definite crystals, but is sometimes found in fibrous concretionary and often earthy masses, and also mixed with sand or clay. It contains from 8·2 to 10 per cent. of water.

It occurs in the upper parts of decomposed pyrites or copper lodes, where it forms the "gossan," and it is also interesting to

note that some of these gossans have been worked for iron ore on the surface and have changed into copper deposits in depth. Where limonite occurs as a result of the decomposition of pyrites it must be expected to contain sulphur, which will interfere in its metallurgical treatment as an ore of iron.

Extensive stratified deposits of these ores occur in Europe, where they are known as oolitic iron ores. Their percentage of metallic iron is low, from 25 to 30 per cent., but they form beds sometimes over 40 feet in thickness and covering an area of over 50 miles in extent.

The so-called "bog iron ores" which are sometimes very rich belong to this group, as also do the "pisolitic ores" which occur in pebble-shaped concretions about the size of a pea.

Magnetite exists in lodes, beds, and segregations, and also as impregnations in crystalline schists, generally associated with such minerals as chlorite, hornblende, and garnet, which are rich in iron, as well as with quartz. Some of these deposits are similar in character to the hæmatite deposits of Cumberland.

In some places magnetite occurs in very extensive deposits sufficient to affect the working of the magnetic needle at a considerable distance. The ore when pure contains 72 per cent. of metal, and is the richest ore of iron; but impure magnetites also exist in which the contents of metal is as low as 40 per cent.

Siderite, or spathic iron, occurs in lodes, beds, and segregations. This ore is nearly always mixed with the isomorphous carbonate of manganese, diallogite, which increases its value for the manufacture of steel. Siderite in lodes often contains sulphides, which necessitates roasting the ore before smelting; but when decomposed at the surface it affords a valuable ore composed of an earthy mixture of iron and manganese oxides free from sulphur.

Another variety of siderite occurs in lenticular concretions or disconnected beds, in the coal measures of Europe; and, in consequence of its concretionary or banded structure, it is called sphero-siderite or clay band; and a variety mixed with carbonaceous matter is known as "black band ironstone." This ore often contains phosphorus.

Titanic Iron is mostly found as sand formed by the degradation of rocks of eruptive origin, which contain it as grains or small crystals, and in that form it exists as extensive deposits on the west coast of New Zealand at Taranaki and elswhere. Titanic iron crystallises in the same form as hæmatite, and consequently occurs in mixtures of no definite composition. It has already

been alluded to in the chapter on tin, as forming part of the so-called "black sand," so often met with in alluvial deposits. Titanic iron is also found in veins or beds in diorite, as in Norway, where crystals occur weighing as much as 16 lbs. It cannot be considered as a valuable ore of iron, as the presence of titanic acid makes it very difficult to smelt, although a small quantity is said to improve the quality of steel.

Vivianite, a phosphate of iron, is a mineral of a deep blue or green colour. It is found with iron, copper, tin ores, &c., and is often crystallised in old bones which have been buried and partially decomposed in ferruginous soil; and also in beds of clay.

Sulphate of Iron, a soluble salt, occurs as a greenish efflorescence from the decomposition of iron pyrites. With tincture of galls it gives a black colour and is the basis of common ink.

TABLE OF NATIVE AND OXIDISED IRON ORES.

Mineral.	Chemical State.	Metal per cent.	Hardness.	Specific gravity.	Streak.	Remarks.
Native iron, .	Nearly pure	...	4½	7·78	...	Rare—in some lavas.
Meteoric iron,	Alloyed with nickel, &c.	Ni 4 to 16	4½	7·78	...	Extra-terrestrial origin.
Magnetite, .	Oxide	72	5½-6½	5	Black	Strongly magnetic.
Titanic iron, .	Iron and titanium oxides	Variable	5-6	4·7-5·3	Black or brown	Often occurs as sand; slightly magnetic.
Hæmatite, .	Anhydrous oxide	70	5½-6½	5·25	Cherry-red	Rhombohedric, massive or micaceous.
Goethite, .	Hydrous oxide	63	5-5½	4·3	Ochre-yellow	Often fibrous or concretionary.
Limonite, .	Do.	62	5-5½	3·6-4	Do.	As above or earthy.
Siderite, .	Carbonate	Variable	3½-4½	3·8	Light-brown	Crystallised, lenticular, &c.
Vivianite, .	Phosphate	...	1½-2	2·7	Bluish	Rarely crystallised, earthy.
Sulphate of iron (copperas),	Sulphate	...	2	1·83	...	Soluble, green—from decomposition of pyrites.

It must be remembered that the percentage given in the third column are those of pure, or nearly pure, minerals, and that ordinary ores will be poorer because of the impurities contained in them; this observation applies equally well to all the similar tables.

Iron Pyrites.—All the minerals under this head give a magnetic mass when heated on charcoal before the blowpipe. Every prospector knows the common yellow pyrites to which he refers as "mundic" and not one will mistake it for gold, although some specimens have a beautiful golden colour. The most ready test is its hardness, which enables pyrites to strike fire with steel, giving at the same time a smell of sulphur.

There are two species of iron pyrites of the same composition, but crystallising differently. "Pyrite" is the mineralogical name of the species which crystallises in cubes and modifications of the cube; the name "marcasite" being reserved for the other species which, being of a paler yellow, is often called "white pyrites," but must not be confounded with mispickel, known amongst miners as "white mundic." Marcasite crystallises in prisms, which often affect the form of tables.

Both pyrite and marcasite are found in concretions, stalactites, and radiated balls. Their hardness is the same, but the specific gravity of marcasite is less than that of pyrite. They are both readily decomposed, especially when exposed alternately to the sun and rain; this property is sometimes taken advantage of in lixiviation processes for the recovery of gold or preparation of sulphate of iron. Marcasite, however, decomposes with greater facility than pyrite. It is often found replacing the carbonate of lime in fossil shells, and these are difficult to preserve unless covered by a substance which prevents access of air. It is to the decomposition of marcasite and pyrites, and the heat generated during the process that many of the fires in coal mines and on board ship, said to originate from spontaneous combustion, are due.

There is another kind of pyrites which is not of such common occurrence—viz., magnetic pyrites or pyrrhotine. It contains more iron than the common pyrites and is slightly magnetic in its natural state; its colour is also different, being bronze-yellow.

Mispickel, commonly called "white mundic," differs in composition from the other forms of pyrites by the substitution of arsenic for part of the sulphur; its tin-white colour makes it an easy matter to recognise it. Its hardness is not so great as that of ordinary iron pyrites, but it also strikes fire with steel, and then gives a smell of garlic, due to arsenic. It

will be easily distinguished from arsenical cobalt (smaltine) and grey nickel (gersdorffite), which it resembles, by the borax assay before the reducing flame of the blowpipe. With smaltine the bead will be blue, and with gersdorffite light green, when cold, if cobalt is absent; while the borax bead, with mispickel, would give the reaction of iron—viz., bottle green when cold. The bead of nickel and the bead of iron will be best distinguished in the oxidising flame; when cold, the nickel bead is red, while that of iron is light yellow or colourless.

Common iron pyrites occurs as an accessory mineral in all metalliferous veins. It always accompanies gold in the reefs, when this precious metal is free; and is generally auriferous itself to a greater or less extent, being seldom free from traces of gold even when free gold does not occur in the district.

From an industrial point of view pyrites should be considered as an ore of sulphur, being used in the manufacture of sulphuric acid, the sulphates, and sometimes sulphur itself.

In sedimentary rocks pyrites is frequent, especially in fossiliferous beds, having been deposited in them by the decomposition of organic matter. As a rule, marcasite is the variety found in sedimentary formations which have not been metamorphosed, while pyrites occurs in lodes and metamorphic rocks.

It has been said that pyrites is easily decomposed in Nature. This decomposition takes place in two different ways. In the first, a soluble sulphate of iron is formed with the generation of heat; this explains in some cases the high temperature of mines and mineral springs. In the second, the sulphur is slowly displaced and hydrous oxide of iron formed; this explains how it is that at the surface, or in exposed parts of a pyritous deposit, cubical crystals of limonite frequently occur, which, if broken, are found to contain a nucleus of undecomposed pyrites in the centre.

Magnetic pyrites often contains from 3 to 10 per cent. of nickel, and is then mined for that metal. Nickeliferous pyrrhotine occurs in veins in diorite in Italy, and in porphyry in Scotland, at the contact of gabbro with the country rock.

Arsenical pyrites is practically an ore of arsenic, but often contains gold or silver. It is more frequently associated with tin and copper ores.

TABLE OF SULPHURETTED IRON ORES.

Mineral.	Iron combined with	Useful Substance. Per cent.	Hard-ness.	Specific Gravity.	Streak.	Remarks.
Pyrite, .	S	S 54	6–6½	5	Grey	Often auriferous.
Marcasite, .	S	S 54	6–6½	4·8	Greyish-green	Very easily decomposed.
Pyrrhotine, .	S	S 39	4	4·6	Dark-grey	Slightly magnetic; sometimes nickeliferous.
Mispickel, .	S, As	As 43	5·5	6·1	Black	Sometimes auriferous.

S, Sulphur ; *As*, Arsenic.

Nickel and Cobalt.

The ores of nickel and cobalt are of two classes—viz., those in which the metals are combined with arsenic, sulphur, or both; and those in which the metals are oxidised.

The first class includes all those ores which are mined in Europe, where they exist in veins in granite, gneiss, or schists, and at the contact of these rocks with diorite, gabbro, &c. In these deposits the oxidised or surface ores are relatively rare; but in New Caledonia they form extensive deposits in serpentine and associated rocks, and have been segregated from these rocks into fissures of more or less importance.

The ores of nickel and cobalt, which are mostly arsenides, generally occur together; and, in Germany, accompany some copper and silver ores. In most of the European ores the proportion of cobalt is nearly one-tenth that of nickel, and the most common ore of nickel in Europe is nickeliferous pyrites or **nicopyrite**. At Val Sesia in Italy it occurs at the junction of diorite with hornblendic gneiss.

At Eterlien in Norway the same ore also occurs in a contact deposit between schistose quartzite and gabbro, and sometimes the gabbro itself is sufficiently impregnated to be worked to advantage. In Sweden it forms large veins in granite, and is generally accompanied by other sulphides, especially copper pyrites.

The mineral of next importance is copper nickel, or **niccolite**, which occurs in Austria in veins traversing talcose and hornblendic schists, some beds of which are impregnated with pyrites.

and mispickel. The ore there also contains white nickel or chloanthite, besides copper nickel and argentiferous grey copper. Although the nickel and cobalt ores are not easy to recognise at a glance they will generally be detected on working the outcrops of lodes by the stains which proceed from their decomposition. These are oxidised products in the form of arseniates, and they are generally found accompanying the arsenides. The arseniate of cobalt is of a pink or peach blossom colour and is known as "erythrine" or "cobalt bloom"; and the arseniate of nickel, called "annabergite," is apple green. That the ores of nickel frequently contain cobalt is illustrated by the fact that both these stains often occur on the same specimens of ore.

At the present time the nickel and cobalt industries are rapidly increasing, since abundant deposits of those metals have been found and worked in New Caledonia and Canada.

The ore in New Caledonia is a hydrous silicate of magnesia more or less impregnated with oxide of nickel, and containing, as an average, 8 or 10 per cent. and sometimes even 30 per cent. of nickel in picked specimens. It occurs in veins 2 feet or 3 feet thick and over, in a decomposed serpentine.

The best ores are sometimes mixed with rounded fragments of serpentine, forming a kind of "breccia"; but these veins have not been found to continue rich to great depths. The form of the best quality of ore, which is of a beautiful emerald green colour, is concretionary or stalactitic. It has evidently been segregated from the enclosing serpentine which sometimes contains ·25 per cent. or even nearly 1 per cent. of nickel. These minerals have been named Noumeite and Garnierite, but they do not appear to have any very definite chemical composition, the percentage of nickel varying within somewhat wide limits.

The cobalt ore of New Caledonia is an earthy manganese oxide called **Wad** mixed with a small percentage of oxide of cobalt from 2 to 15 per cent. It is found in decomposed serpentinous rocks, in nodules and small veins of concretionary structure; and sometimes also encrusting roots of trees, thus showing that the percolating liquids from which it was precipitated are still in circulation.

Blowpipe Tests for Nickel and Cobalt.—In using the blowpipe for the determination of nickel and cobalt minerals the following notes will be of value when the two occur together, either in the same mineral species or mixed together as in some mines. The mineral should be heated on charcoal so long as arsenical fumes escape and then fused with borax. If there is no iron present the bead will be blue; but, if there is much iron,

it will be first bottle-green, changing to bluish-green. The bead must then be removed from the platinum wire and heated in a fresh borax bead which will then become blue. More borax should be added as long as the bead shows any blue colour in the oxidising flame, the blue borax being broken off after each operation; and eventually, if there is nickel in the ore, the bead will be coloured brown. If the presence of copper is suspected, it will be recognised by fusing the last borax bead with microcosmic salt; if copper is present the glass will become green. With the information thus gained and the characters enumerated in the tables it will be easy to distinguish the different minerals.

TABLE OF COBALT AND NICKEL ORES.

Mineral.	Combined with	Metal. Per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Millerite, .	S	Ni 64	3½	5·2	...	In capillary brass-yellow crystals.
Nickeline or copper nickel,	As	Ni 44	5–5½	7·5	Deep brown	Reddish-grey or pale copper.
Chloanthite or white nickel,	As	Ni 28	5½–6	6·5	Greyish	Tin-white.
Gersdorffite, .	As	Ni 32	5½	6·1	Greyish-black	Silver-white or steel-grey.
Nicopyrite, .	S	Ni 20	3½–4	4·6	Light-bronze	Not magnetic.
Linnæite, .	S	Ni 33, Co 22	5½	5	Dark-grey	Steel-grey.
Cobaltine, .	S, As	Co 35	5½	6	Grey	Silver-white or reddish; distinct cleavages.
Smaltine, .	As	Co 28	5½	7	Greyish-black	Tin-white or steel-grey.
Glaucodote, .	S, As	Co 24	5	6	Black	Deep tin-white; rare.
Cobaltiferous mispickel,	As	Co 10	5½–6	6 2	Greyish-black	Deep tin-white; rare.
Annabergite, .	Arseniate of nickel	...	Soft	...	Pale-green	Earthy; apple-green.
Erythrine, .	Arseniate of Co.	Co 37	1½–2½	2·9	Pale-pink	Pink or peach-blossom.
Garnierite, .	Silicate	Ni 10–30	2–2½	2·3	Pale-green	Apple-green, pale bluish-green, &c.
Noumeite, .	Silicate	Ni 5–20	2–2½	2·5	Do.	Emerald-green, apple-green, &c.
Cobaltiferous wad,	Oxides	Co 2–15 Mn 50–60	1	3·7	Black with a bluish shade	Earthy concretionary.

S, Sulphur; *As*, Arsenic; *Ni*, Nickel; *Co*, Cobalt.

Manganese Ores.

Manganese is very extensively disseminated in nature; it occurs in veins even in the earliest formations, and in irregular deposits in sedimentary beds.

In Thuringia and the Hartz these ores occur in veins in porphyry, but while in the first region pyrolusite and psilomelane predominate with heavy spar and other associated minerals; manganite and hausmannite with heavy spar, &c., constitute the filling of the veins in the Hartz.

At Romaniche in France an extensive deposit of manganese ore exists forming the cement of a breccia in a rock which is formed by the disintegration of granite and is called "arkose." This deposit is connected with a true vein in granite, one fathom wide, filled with manganese ore.

In the Devonian rocks of the Rhenish mountainous region deposits of manganese occur in the magnesian limestone or dolomite. Some of these deposits are impregnations, which have in part proceeded from a vein; but the principal deposit consists of nodular concretions in clay on the surface of the dolomite. The upper beds contain pyrolusite, and the lower psilomelane, the latter ore originating, no doubt, from the alteration of pyrolusite by percolating waters.

The analogy between the two last deposits is evident, and shows how easily manganese is segregated. It occurs, even in the most recent formations, in thin coatings which sometimes affect the forms of ferns and are termed dendritic markings.

The principal deposits of manganese, however, are very irregular both in form and extent; large lenticular masses occurring in slate, which, when worked out, give no indications whatever leading to other deposits.

The ores of manganese are extensively employed in the manufacture of steel, but for that purpose they must be free from phosphorus and sulphur. The oxides which are richest in oxygen and poorest in metal—viz., pyrolusite—are used for the generation of chlorine and also for preparing oxygen.

In the manufacture of glass, manganese is used for destroying the bottle-green colour given by iron, and in consequence is termed by the French "*savon des verriers*" or "glass maker's soap." When cobaltiferous manganese is used in the same manufacture, instead of a colourless, a blue glass is made. All manganese ores give a violet or amethyst coloured bead with borax before the blowpipe; and a green mass, if fused with nitre and carbonate of soda on porcelain.

TABLE OF MANGANESE ORES.

Mineral.	Chemical State.	Metal. Per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Pyrolusite, .	Anhydrous oxide	63	2-2½	5	Iron-black	Bacillary, radiated.
Braunite, .	Do.	69·6	6–6½	4·7	Brown or brown-black.	... ...
Hausmannite,	Do.	76·9	5–5½	4·8	Brown-red	... ...
Manganite, .	Hydrous oxide	67	3½-4	4·3	Deep brown-red	Bacillar grooved crystals.
Psilomelane, .	Manganate of baryta, &c.,	52	5·6	4	Black or brownish-black	Amorphous.
Wad, . .	Impure	Variable	Variable	...	Greyish-brown	Amorphous nodular.
Alabandine, .	Sulphide	...	4	4	Deep green	Rare — colour iron-black— generally granular.
Hauerite, .	Do.	...	4	3·4	Reddish-brown	Contains less manganese than alabandine.
Diallogite, .	Carbonate	...	3½–4½	3·6	Reddish-white	Pink or flesh coloured.
Rhodonite, .	Silicate	...	5½	3·6	Do.	Pink or peach blossom.

The last four minerals of the table will be easily known. Although the two sulphides, being rare, have not been especially alluded to in the determination of minerals, they will be recognised by the reactions of manganese and sulphur before the blowpipe.

The carbonate (diallogite) and the silicate (rhodonite) are conspicuous enough from their fleshy or peach blossom colours, and will be distinguished from one another by their different hardness. Diallogite will be easily scratched by a knife, while rhodonite will not.

An important deposit of carbonate of manganese occurs as irregular masses in limestone at Las Cabesses, in France, and the percentage is increased by calcination. Diallogite is not a rare mineral in small quantities, and its associations are interest-

ing. It has been found with gold, silver, lead, copper, and the other ores of manganese.

Rhodonite is found in some iron mines and also in association with tetrahedrite, and some very beautiful specimens are obtained at times.

Chromium.

The only ore of chromium is **Chrome Iron**, and this ore is found in many localities, associated with serpentine, but sometimes its gangue is olivine. The rock dunite, first described from New Zealand, consists of olivine through which chromite is dispersed as grains. In New Zealand and New Caledonia chrome iron occurs in veins, and it is an abundant ore in the Shetland Islands, as in Unst, &c.

Chrome iron exists as large masses in some serpentines, especially those containing diallage, and sometimes as concretions through the same class of rock. From the decomposition of this rock it occasionally forms a wash or black sand on the sea shore, as in New Caledonia, in the same manner as titaniferous iron does in New Zealand. There are extensive deposits of chromite in Asia Minor.

Serpentine generally contains ores of iron, but these always contain a few units per cent. of chromium, which interfere with the metallurgical treatment; although, chrome steel is now somewhat largely manufactured, and is of especial value for the heads and dies of stamper batteries.

Chromium is used chiefly in the state of chromate and bichromate of potash in dyeing, and also in the manufacture of colours.

Uranium.

Pitchblende is a mineral which is usually massive, black, and with a pitchy appearance; it is composed of the metal uranium and oxygen, and always contains lead, iron, &c. There are other uranium minerals, such as **uranium mica**, &c., which have a characteristic yellowish-green colour, but pitchblende is the permanent ore in depth.

It occurs in several lead mines in Germany, has been worked as the principal ore in a mine near Grampound Road, in Cornwall, and is found in some other deposits. It is used in the preparation of uranate of soda, which affords a pretty orange colour for painting porcelain and colouring glass, to which it imparts a greenish-yellow, foggy, or opaline appearance.

CHAPTER XVI.

Sulphur—Antimony—Arsenic—Bismuth.

Sulphur.

In some districts sulphur occurs native, associated with gypsum, the most common of the sulphates. It is chiefly found in volcanic districts, such as Sicily, Popocatapetl in Mexico, and White Island in New Zealand. It is also occasionally formed by the decomposition of pyrites, both in coal and metalliferous mines. Its varied applications class it as a raw product of primary importance. It is used for the manufacture of sulphuric acid, and for making gunpowder, and the property which it possesses of expanding on cooling makes it valuable for taking casts of medals, bas reliefs, &c.

Arsenic.

Native arsenic is rare, but occurs as an accessory mineral in some antimony and silver mines, in crystalline and schistose rocks; and it is also found in the Kapanga gold mine in New Zealand.

The two other arsenic minerals, orpiment and realgar, were amongst the earliest known minerals, their conspicuous colour, which rendered them valuable for the manufacture of paints, having attracted the attention of the ancients.

Orpiment is a compound of sulphur and arsenic, and has a beautiful golden colour, with a nacreous lustre on the cleavage faces, while that on the fracture is dull or resinous.

Realgar differs in composition from orpiment by containing more arsenic, and its colour is orange-red. It is often well crystallised, and is accompanied by orpiment, into which it changes on exposure. Realgar is found with orpiment and native arsenic in metalliferous veins, especially those of silver, gold, and lead, in Transylvania. It is also mentioned as occur-

ring in gypsum and dolomite, and both orpiment and realgar are often associated with products of volcanic eruption.

TABLE OF SULPHUR AND ARSENIC MINERALS.

Mineral.	Composition.	Hardness.	Specific Gravity.	Streak.	Remarks.
Sulphur, .	Native	$1\frac{1}{2}$-$2\frac{1}{2}$	2	...	Yellow; very brittle.
Arsenic, . .	Do.	$3\frac{1}{2}$	5·9	...	Metallic lustre; tin-white or grey.
Orpiment, .	S, As	$1\frac{1}{2}$	3·48	Yellow	Orange-yellow.
Realgar, . .	S, As	$1\frac{1}{2}$	3·55	Orange-red	Deep orange-red.

Antimony.

The only ore of antimony is the sulphide, known as antimony glance or stibnite, the oxides which occur with it being merely products of secondary formation, while native antimony is rare and occurs mostly with ores of silver, although it is found with gold in the Wentworth mine in New South Wales.

Although stibnite resembles galena, it will be readily distinguished by being easily fusible in the flame of a candle, by the white fumes evolved; and by its form, which is generally that of elongated or fibrous crystals; while galena is granular, or lamellar with cubical cleavages. In some fine-grained varieties, however, these differences disappear, and the fusibility and other blowpipe reactions have to be depended upon.

It will be more difficult to decide if a mineral is an accidental mixture of galena and stibnite, because it might then be confounded with one of the rare minerals jamesonite, zinkenite, &c., which are sulphides of antimony and lead.

Both of the oxides mentioned in the table occur either crystallised, fibrous, or earthy, and are products by the decomposition of stibnite, which they accompany in the deposits. Masses and crystals of stibnite are sometimes found coated with a yellow substance, which is rather hard and infusible, and which also occurs in fibrous masses or columnar grooved crystals, resembling fossil wood. This is probably another species of antimony ochre, differing slightly in composition from cervantite.

Antimony is generally found in quartz veins, sometimes associated with heavy spar. It is also said to occur with spathic

iron in beds of Devonian age in Germany, where it is probably connected with veins of the same ore.

Stibnite sometimes accompanies gold at Fichtelgebirge, and in the mines of the Thames in New Zealand, and is itself auriferous in Portugal, New South Wales, and elsewhere. Although many processes have been devised for treating ores of this nature, no great success has yet been attained.

TABLE OF ANTIMONY ORES.

Mineral.	Composition.	Metal. Per cent.	Hardness.	Specific Gravity.	Streak.	Remarks.
Native antimony,	A small proportion of lead, silver, and arsenic	...	3½	6·6	Tin-white	Sometimes lead-blue but generally tin-white.
Stibnite, .	Sulphide	71·7	2	4·6	Lead-grey or steel-grey	Striated prisms, fibrous masses or granular.
Valentinite, .	Oxide	83	2–3	5·5	White	White, yellowish, and brownish; nacreous.
Cervantite, .	Oxide	79	4–5	4	Yellowish-white to white	Sulphur-yellow or nearly white, sometimes reddish-white.

Bismuth.

Bismuth is a metal of rare occurrence in nature and, therefore, although not used extensively, it has hitherto commanded a good price; but mining on a large scale would soon overstock the market, and create a depression until new applications of the metal were found.

Bismuth is not found, as a rule, in deposits by itself, but occurs in Europe with cobalt and nickel ores, and also with silver ores and galena; while in New South Wales it accompanies tin and gold, in quartz in which molybdenite is also present.

The principal ores of bismuth are the native metal, of a tin-white rosy colour and very fusible; and **bismuthine** or bismuth

glance, which is the sulphide of bismuth. The oxide and carbonate of bismuth, known as bismuth ochre and bismuthite respectively, are generally found with the other ores by the decomposition of which they are formed; they occur in the upper parts of the lodes.

The easy fusibility of native bismuth, its brittleness when cold, and its white rosy colour are characters which serve to distinguish it readily. The sulphide, bismuthine, generally occurs in small prisms or in a granular form, is easily sectile, and yields a smell of sulphur before the blowpipe, leaving a pale yellow coating of oxide on charcoal.

The oxide forms a yellow coating on the ores just mentioned, and is easily reduced on charcoal to metallic bismuth. The carbonate does not occur crystallised, and will be recognised easily by reduction on charcoal to metallic bismuth and by its solubility with effervescence in acids. The solution will give a white precipitate when distilled water is added to it. Carbonate of bismuth in small rounded pebbles of a yellowish colour is found in New South Wales in some alluvial tin deposits of the North.

In the tin country of New South Wales, at Kingsgate, bismuth occurs in granite and altered slates. The line of junction of the two formations is well defined, and bismuth lodes occur in the granite in proximity to this line, or not more than 400 yards from it. According to the late Mr. C. S. Wilkinson, these deposits are pipe veins or oval masses of quartz of variable thickness, descending in a more or less vertical direction in the granite, as though well-like caverns of very irregular shape had been formed in the granite and filled with quartz and metallic minerals. Molybdenite and mispickel occur in these veins as well as tin. The largest mass of native bismuth found weighed 30 lbs.

North of Glen Innes, bismuth is associated with tin in quartz veins of an irregular character. These veins and masses traverse a fine-grained micaceous felsitic rock, which is surrounded by altered sedimentary beds. They sometimes form networks of veins and sometimes masses of quartz, one of which at surface was 40 feet × 20 feet. Bismuth is here also associated with molybdenite, mispickel, and wolfram, and in consequence of this last mineral being present the lodes can scarcely be profitably worked for tin.

The bismuth ores proper—viz., bismuth glance and native bismuth—are always accompanied by the yellow earthy carbonate and oxide, which are products of their alteration and decomposition.

TABLE OF BISMUTH ORES.

Mineral.	Composition.	Metal. Per cent.	Hardness.	Specific Gravity.	Streak	Remarks.
Bismuth, .	Native	...	2–2½	9·7	...	Brittle, becomes oxidised by exposure to air.
Bismuthine, .	Sulphide	81	2	6·5	Shining	Bacillar or granular, sectile.
Bismuth ochre,	Oxide	72·8	...	4·3	...	Earthy-yellow.
Bismuthite, .	Carbonate	75	4–4½	6·9	Greenish-grey to colourless	Amorphous, yellow, brittle.

CHAPTER XVII.

Combustible Minerals.

THE minerals included in this group are all varieties of carbon or hydrocarbons, and are included in the following table :—

TABLE OF CARBON MINERALS.

Mineral.	Characters.	Hardness.	Specific Gravity.	Remarks.
Graphite, .	Nearly pure carbon	1-2	2·2	Metallic lustre, infusible, soils the fingers.
Anthracite, .	Coke 82 to 90 °/₀	2-2½	1·3-1·7	Semi-metallic lustre; burns with difficulty.
Coal, . .	Coke 60 to 82 °/₀	2-2½	1·2-1·7	Lustre resinous; burns with bituminous smell.
Cannel coal, .	Yields large quantities of gas	...	1·26	Fracture conchoidal; burns freely.
Lignite or brown coal,	Hydrous coal	1-2½	·5-1·25	Dark brown streak; burns with a disagreeable smell.
Torbanite or kerosene shale,	Vol. Hydrocarbons 60 to 80 °/₀	...	1·05-1·30	Fracture conchoidal; burns freely.
Elaterite or mineral caoutchouc,	Hydrocarbons— Carbon . 58 °/₀ Hydrogen 12·5 °/₀	...	·9-1·0	Burns freely with bituminous smell.
Ozokerite or mineral wax,	Hydrocarbons— Carbon . . 85 °/₀ Hydrogen . 14 °/₀	...	·85-·90	Like wax; greasy; burns freely.
Petroleum, .	Hydrocarbons— Carbon . . 84 °/₀ Hydrogen . 16 °/₀	...	·70-·90	Burns with a peculiar smell.
Amber, . .	Oxygenated hydrocarbons— Carbon . . 79 °/₀ Gas . . . 21 °/₀	2-2½	1·1	Resinous, yellow; electric by friction; burns with an aromatic smell.
Asphaltum, .	Oxygenated hydrocarbons— Carbon . . 76 °/₀ Gas . . . 22 °/₀	·2	1·2	Easily fusible; streak black or brown; burns with a smoky flame and a bituminous smell.

N.B.—Percentages vary, but those given are fairly typical.

Diamond is the purest form of carbon. It is combustible, but requires great heat to burn it; and, being the most valuable of our gems, as well as the hardest substance in nature, is more properly considered in this book with the gems or stones harder than quartz.

The diamond, graphite, anthracite, the coals, lignites, and, lastly, wood and other vegetable matter all form carbonic acid when burned; but from some of them hydrogen and its compounds, especially hydrocarbons, are also evolved, a regular series thus existing through the bituminous and cannel coals to the true hydrocarbon minerals, such as petroleum and mineral wax.

Next to the diamond in purity comes **graphite** or **plumbago**, which is found in the earliest and most highly metamorphosed formations, where it represents the vegetation of those times, which has, under pressure, lost all it volatile constituents, and been also rendered schistose by metamorphic action. It is very valuable when pure and massive, and its wide application in the manufacture of lead pencils and crucibles is well known. It will be readily recognised by comparing it with the lead of pencils. Inferior qualities have to be thoroughly washed, prepared, and pressed, while pure varieties can be sawn in their natural state.

Coals.—Coal seams, as already pointed out, are formed from vegetable matter; but it was while the deposition of the various sandstones, &c., which overlie them, was going on that the character of the carbonaceous deposits first began to change; great weight was put upon them, in the first instance, by the overlying rocks and thus they became solidified, and, by means of this pressure, and the heat induced by pressure, chemical action set in, which had the effect of slowly driving off the more volatile constituents of the coals. Water and various hydrocarbons were driven off, and the carbonaceous beds, which at first very nearly approximated to the composition and character of wood, were by degrees changed into coal.

This process of carbonisation is, however, by no means complete, except in a very few instances; and it is chiefly by the state of change that has been effected that the coals are classified as follows:—

Hydrous coals containing over 10 per cent. of water,	Lignite. Brown coal. Pitch coal.
Anhydrous coals containingless than 10 per cent. of water,	Cannel coal. Steam and household coal. Anthracite.

Those coals which contain over 10 per cent. of water have suffered less change than the others, and they have many disadvantages as compared with the anhydrous varieties. These hydrous coals are sub-divided, by their physical characters, into *lignites, brown coals,* and *pitch coals ;* but it is very hard to draw a clear and distinct line between them. Thick deposits of brown coal are found in various localities; at Lal Lal, in Victoria, the beds are 150 feet thick and are covered with basalt; and in New Zealand extensive deposits are mined both in the north and south, the seam at the Miranda colliery being 55 feet thick.

When the better class of these hydrous coals are first taken from a mine, they would frequently puzzle any but an experienced observer to distinguish them from the true coals. They have a compact structure, are black and shining, and in many other ways bear a strong resemblance to the true coals. If, however, they be left exposed to the air for some time one has no difficulty in distinguishing them, for they begin to lose their water, and, in doing so, crack in all directions and then fall to pieces. This being the case long transport is impossible, and the employment of the coal must be purely local; moreover, it must be burned as soon as it is raised from the mine as stacking on the ground will reduce its value.

These hydrous coals, however, are of considerable value where true coals are not obtainable, and will even compete very favourably with them when the true coals have to be brought from a distance; but they have another disadvantage from the occurrence of water in their composition—viz., that the water is not only unable to supply any heat itself, but requires a certain amount of heat to convert it into steam; and for this reason, where both classes of coal are readily obtainable, it is frequently preferable to employ an inferior class of anhydrous coal rather than the best lignite, brown or pitch coal.

The anhydrous coals, as before stated, may be divided into

Anthracite or non-bituminous coal,
Cannel or highly bituminous coal,
Steam or household or less bituminous coal,

and many other sub-divisions are also made to which it is not necessary to call attention.

Anthracite is coal in which the process of carbonisation has been pushed to its greatest extent. It never contains less than 80 per cent. of carbon, and is frequently almost entirely composed of it. Anthracite does not soil the fingers, and is of a

glossy black appearance; it is difficult to kindle, but in burning gives off an intense heat with little or no smoke. From the difficulty in burning it is not so well adapted for household consumption as the free burning coals, although it is largely used in America for that purpose. It is principally employed in smelting metals and raising steam.

Cannel Coal, again, does not soil the fingers, but in other respects differs materially from anthracite. It has received the name of cannel from the property it possesses of burning readily with a flame like a candle. It is highly bituminous or contains a large proportion of volatile matter, and is principally employed in the manufacture of gas. Although other coals are also employed for gasmaking, the quantity of gas obtained from them is generally less than, and the quality always inferior to, that made from cannel.

The ordinary or household coals may be variously subdivided according to the properties which each possess, but the only one of importance is between the caking and non-caking coals.

Caking Coals are those from which, in burning, there exudes a black bituminous substance which cements the coal together, in the fire, into a pasty mass. This class of coal is the one from which coke is chiefly made, and is also used both for domestic purposes and for raising steam. The other, or *non-caking coals,* do not run together when heated, and are of a more free burning character.

Jet is a variety of coal, is black, and takes a good polish. It is of value for the manufacture of ornaments, such as crosses, earrings, &c. The most important deposit known is that of the Jurassic coal measures, near Whitby, in Yorkshire, where two qualities are found, one very hard and valuable, another softer and of less value.

The bog oak of Ireland must not be confounded with jet; it is simply wood impregnated with iron, and occurs in swamps where iron ore is forming at the present day.

The name of jet is commonly given to black glass beads and glass jewellery, but these are not likely to be mistaken for the genuine article. Jet is much lighter and not so brittle as glass, but its origin does not appear to be well understood. It is described by some authors as a variety of lignite, but it is anhydrous, and is generally associated with cannel coal; it is very probably a fossil gum. Jet occurs in the Hartley Vale and Joadja Creek shale mines in New South Wales, as thin seams which have no great lateral extension.

Petroleum.

Petroleum is composed of hydrocarbons, and is found in rocks of all ages, sometimes in subterranean reservoirs of great extent.

In Pennsylvania, sandstones saturated with oil, form the reservoir, and these sandstones appear to be lenticular in form, and of varying texture, sometimes passing into conglomerates. The following facts appear to have been ascertained with reference to the Pennsylvania oil region.

1. The thicker the cover the more the oil, large accumulations being seldom found under light covers.
2. The coarser and more open the sand the more the oil.
3. The sandstones buried in shales must form the reservoir.
4. Underlying shales must exist which form the source of the oil.

In the Ohio district the Trenton limestone, which is struck at a depth of from 1100 to 2200 feet below the surface, and is covered by 400 to 1000 feet of shales, appears to be both the producer and reservoir. The principal accumulations, both of oil and gas, are always in the uppermost beds of the limestone, and generally not more than 20 or 30 feet below its upper surface. The oil rock continues to a lower level, but below the oil the rock is charged with brine containing unusual quantities of chloride of calcium and magnesium; when this is struck the well is frequently lost, although it is sometimes possible to plug it near the bottom.

The limestone appears to be quite porous in parts, but this porosity seems to be due to dolomitisation, the change having resulted in recrystallisation which has left innumerable microscopic cavities in which the oil has accumulated.

There appears to be no doubt that petroleum has been derived from organic matter and much more largely from vegetable than animal substances; it has, moreover, been produced in most cases at the normal rock temperature, and is not a product of destructive distillation of bituminous shales.

Where flat anticlines exist, the paying wells are almost always on the domes, whether these be the main ones or those of smaller elevation situated at points in the synclines. This is still more the case with gas wells, and where gas and oil have been struck at other points they are, very generally, soon overpowered by salt water.

Petroleum has generally been found in consequence of a discovery of inflammable gas, sometimes escaping from fissures

in the surface of the ground, and, in other cases, struck when sinking wells. In some instances this gas occurs in vast quantities, and has been used extensively for heating and lighting purposes.

The discovery of indications, however, affords very little information as to the best localities for sinking wells, and in the early days of an oil field there is a great deal of chance in the location of a site. When, however, several bore holes have been put down, information is gained which serves as a guide, and fewer mistakes are likely to be made.

Some oil-bearing rocks, such as the Boghead mineral or torbanite of Scotland, and the similar oil-bearing shale of New South Wales seem to have been formed in a similar manner to coal, but under different conditions.

The last rock, known as "kerosene shale" occurs in lenticular beds of considerable extent in the coal measures and probably differs only from coal itself by being composed of the remains of swamp plants, which have undergone decomposition under water, in special conditions capable of preserving most of the gases. If microscopical examination does not detect any organic structure as in coal, it is most likely because the water plants were of a much softer nature than those which formed the coal, and that the cells have been completely destroyed by fermentation.

An abundant source of petroleum is to be found in the oil-bearing schists, or, as they are sometimes incorrectly termed, bituminous schists. According to Dufresnoy the oil in these schists originates from the decomposition of animals, especially fishes, the fossil remains of which are abundantly found; but this, if true in one instance, can hardly be considered as universally correct. Petroleum occurs in different formations, from the carboniferous to the tertiary.

Mineral wax or *ozokerite* is a solid petroleum containing from 14 to 15 per cent. of hydrogen, whilst petroleum contains 16 to 17 per cent.

Mineral caoutchouc or elaterite contains still less hydrogen, from 12·3 to 13·3 per cent., than mineral wax. It is found with lead ore and calcite at Castleton in Derbyshire, and in coal mines near Nantes in France, and also in Massachussets. A similar mineral has been found in the Coorong Lagoons of South Australia and named Coorongite.

The bitumens contain 10·3 per cent. of oxygen and hydrogen, and when bitumen regularly impregnates rocks of somewhat homogeneous composition, such as limestones, it forms a material

which is highly prized for footpaths, flagstones, &c. For that purpose it is crushed to powder, melted, and used either with or without additional sand and pebbles. When refined in powder it can be set dry and agglomerated with hot irons.

Amber is a mineral resin and, like the bitumens, contains about 10·5 per cent. of oxygen and nearly the same proportion of hydrogen. It resembles kauri gum very closely, and ornaments are made of that substance to imitate amber, but they are more brittle than the genuine article. Amber, as well as kauri gum and other resins, has exuded from trees, and is frequently found fossilised in lignites of Tertiary age.

CHAPTER XVIII.

GENERAL HINTS REGARDING PROSPECTING.

Having now described the modes of occurrence of minerals which are most common, and the means which are best adapted for distinguishing one mineral from another, it only remains to give a brief summary of the operations which are necessary for the prospector to adopt for the discovery and tracing of ores, together with such development as may fairly be expected of him, before the discovery is in such a state as to induce capitalists to provide sufficient money to open the mine.

The student may expect some hints regarding the outfit he will require and the operations he will have to undertake, but there is little that can be said which will be of much use to him. With the exception of the few blowpipe accessories which have been enumerated, a compass, and a small prospecting pick, he will be able to secure any equipment he may find necessary at the nearest store, from which he also obtains his provisions; and so he will avoid being encumbered with tools, tents, &c., until he has actual need of them.

Equally is it the case that no description of the methods of sinking shafts and driving levels will be of much use to the student who proposes to work in a practical manner, for a week's residence in a mining camp will afford him more information on these subjects than he could obtain by reading, and he will generally find it to his advantage to do a little work on a claim before starting out to prospect on his own account.

It may be well to recapitulate a few points which have been already alluded to in the foregoing pages.

Metals and minerals may be found either associated with the

rocks in which they were originally deposited, in which case they are called "mineral deposits," or, having been worn away by the action of the weather and transported by running water, they may occur associated with gravels and sand in existing streams or buried river channels, in which case they are spoken of as "alluvial deposits."

The metals and minerals that are found in alluvial deposits are few in number, and for all practical purposes may be limited to gold, platinum, tinstone, and gems, although certain rare minerals, such as osmiridium, are also found now and then.

Owing, however, to the great value of the minerals mentioned above which are found in alluvial deposits, and the fact that a very large proportion of the gold which has been won during historical times has been obtained under these conditions, alluvial deposits demand very careful attention. They are of the greater importance to the prospector because, in many cases, alluvial gold and tin are found under conditions which require no capital to work them, and, consequently, immediate returns can be obtained when the discovery has been made.

These alluvial deposits have been described under the chapter devoted to this subject, but some remarks regarding prospecting for them will be of value, and it must be understood that it is assumed that the district being prospected has not been previously tested.

River beds and creeks should be carefully examined, a pick and a shovel, a tin dish, and a large knife being all the equipment necessary. In the first place, the gravels of the streams should be washed carefully with the object of determining whether any gold at all exists. Next, certain beaches along the course of the stream should be selected (see p. 132) and shallow pits sunk through them until bed rock is met with, and all the material raised should be panned, bearing in mind that the best gold is generally found on the bed rock.

A further test should be made by carefully following up the stream, especially when it is low, and cleaning out with a knife all crevices in the rocks in which gravel and sand have accumulated, and this should all be panned. In some cases, very large quantities of gold have been saved by prospectors in a short time from "crevicing" in this manner.

In certain dry countries, as, for instance, in Western Australia, the rainfall is not sufficient to carry the gold broken down from the reefs for any distance. In such cases there are flats of greater or less extent in which gold occurs through the surface soil for a depth of a few feet.

Where sufficient water is available to wash these deposits, very good returns can frequently be made, and, indeed, a large quantity of gold has been saved by "dry blowing." The most primitive system adopted is, after the larger stones have been screened out, to hold one dish shoulder high, and gradually pour the auriferous sand into another dish on the ground, the wind blowing away the lighter particles and allowing the heavier gold to fall into the dish. This operation has to be repeated several times; but it will be evident that by this method of treatment a good deal of gold must be lost, and also that what gold is saved cannot be properly cleaned; so that water will be required for the final operation.

Deposits of this class are most usually discovered in the first instance by nuggets of gold being picked up accidentally on the surface, but when one or two of these have been found, prospecting by dry blowing is often resorted to over considerable areas.

These surface deposits must necessarily exist in the vicinity only of the reefs or lodes from which they have been shed, and their occurrence affords considerable inducement to prospect for reefs in the immediate neighbourhood; but the gold which is found in rivers and streams does not necessarily point to the close proximity of the reefs from which it was derived; still less does the occurrence of alluvial gold in buried river beds indicate the proximity of reefs.

It is very difficult to enunciate any rules for prospecting for these buried deposits, but a careful prospector will often notice that a river or stream which he is testing, appears at certain points to have altered its course; having, in fact, found it easier to cut a channel in a different direction to that which it originally followed, it has done so leaving its former channel, with the gravels and sands it had deposited, high and dry.

In cases such as this, it is generally worth while to sink prospecting shafts through the gravels until bed rock is reached; and, if the first is not successful, others should be sunk towards the deeper part of the channel as defined by the inclination of the bed rock where it is met with. There are, of course, comparatively few prizes and many blanks in prospecting such as this, but the value of the deposits found at times, offers inducements to prospectors to continue trying, even when but small success has attended their earlier efforts.

Perhaps the most important point with which the alluvial prospector has to make himself acquainted, is what value of ground will pay him to work, and as regards this no information of any

worth can be given in a book, seeing that conditions vary in each particular case. He will, however, very quickly discover how much gold he can extract in a day with the means at his command; and, comparing this with the cost of living and the time he has had to expend in sinking his shafts; taking into consideration, moreover, the amount of ground that he is able to hold in compliance with the laws of the country, and the area that can be worked from each shaft: he will be enabled to form a very accurate idea of what the claim is worth to him.

There are many cases in which the amount of gold found is not sufficient to pay the individual miner to work, but in which, if concessions of a large area can be obtained, and a water supply can be secured sufficient for all requirements, a judicious expenditure of capital for working on a large scale will frequently well repay the cost. Under most favourable conditions, with practically unlimited water and a sufficient space for the deposition of tailings, as low returns as 2½d. per cubic yard can be made to pay handsomely.

The occurrence of alluvial gold or tinstone leads the prospector to examine the country for the reefs from which these have been shed, and a careful study of the conditions which prevail will afford much information. In the case of surface deposits, it is evident that the country in the immediate vicinity should be examined; but where the alluvial deposit has been found in the beds of existing streams or old river channels, it is equally obvious that it may have travelled a long distance from its parent reef. Under these conditions it is necessary to find out whether the alluvial deposits that have been worked are of primary or secondary origin; whether, in fact, they have been broken directly from a reef and have not travelled very far; or whether they have only been sufficiently enriched, by natural sluicing of poor drifts in cross drainage channels, to enable them to be worked to advantage.

In the latter case, the occurrence of alluvial material is no guide whatever as to the vicinity of reefs; but in the former case the stream should be carefully followed towards its source, and the gravel panned from time to time to test how far up stream the gold or tin exists.

So soon as the amount of tin or gold falls off appreciably, the hills on either side of the stream should be examined, which, if they are barren, can easily be done; while, if they are covered with soil and timber, it will be necessary to sink shallow pits or cut trenches in order to lay bare any reefs or lodes which may exist; the soil cut in these shafts and trenches should also be

panned constantly in order to prove whether the right direction is being followed.

When pieces of copper, lead, zinc, manganese, or other ores are found in river beds or on the surface they should be traced in the same manner, always following them up stream as long as any pieces of them can be found; and, afterwards, the hills should be examined until the lode or other deposit is discovered from which they have been broken.

It is, of course, often the case that, notwithstanding all the care that is exercised in tracing broken mineral to its source, no deposits of value are found; and it is equally true that most of the important mines of the world have been discovered by accident; and in many cases by people who have been quite ignorant and wholly unversed in the value of ores. Even, however, if this is the case, an accurate knowledge of the nature of ores and the ability to recognise those which are worthy of attention, places the trained prospector at a considerable advantage, and enables him to utilise chance discoveries made by others who are not so qualified.

An outcrop of mineral having been found, further investigations are necessary to prove the nature of the deposit. The strike having been determined, in the case of a lode, it is first advisable to test it along the surface at various points to prove its continuity and comparative richness at different points. Bearing in mind what has already been stated regarding the existence of shoots of ore, it must not be assumed, because a lode is rich where found, that it will be equally so at all points where it is intersected; and equally, because a lode is poor where first discovered, there is no reason to suppose that further surface prospecting along its course may not disclose parts in which valuable mineral occurs.

It will be within the knowledge of every prospector, even of those with but limited experience, that when a lode has been discovered which carries valuable mineral at its outcrop, other claims are marked out along the course of the lode at either end of the prospector's claim. While this is a perfectly legitimate undertaking, it must be borne in mind that these "position blocks" have only a *prospective* value until the continuity of the lode has been proved, and until it has, moreover, been demonstrated, that it also contains in the ground secured, mineral of sufficient value to pay for extraction.

When surface-prospecting has given as much information as possible, some sinking and driving should be undertaken to prove the continuity and value of the deposit in depth, and here

it is important to emphasise the fact that a prospector's business is to prove, at as small an expense as possible, the value of his discovery, and not to prepare a mine for the ultimate cheapest method of extracting the ore. It is the more important to insist upon this point, because in numberless cases, a lode having been discovered on the surface, the prospector sinks one or more vertical shafts; so located as to strike the lode, if it continues downwards, at a depth of, say, 100 feet from the surface, the shaft being sunk through barren country rock, and proving nothing whatever until the lode is intersected; and, even then, it is only proved at the actual point of intersection, where it may be abnormally rich on the one hand, or on the other so pinched and poor as to offer but little inducement for further work; many good properties have been abandoned by the original prospectors owing to this having happened.

To acquire the greatest amount of information at the minimum cost, the point should be selected on the surface where the reef is at its best, and, having determined the extent along the strike, as nearly as possible, which carries payable mineral, the shaft should be placed about the centre and sunk on the underlay to a depth of 100 feet, or less, if the water level is reached sooner; and, from the bottom, levels should be driven along the course of the lode as long as the mineral is of sufficient value to pay.

It will be seen that by these means a block of ground can be cheaply opened, in which a certain quantity of ore can be measured and sampled, and an accurate idea of its value obtained. In measuring up quartz it is usual to estimate 13 cubic feet to the ton, in the solid, so that a vein 3 feet wide proved to a depth of 100 feet, and for 100 feet along its line of strike would contain $\frac{100 \times 100 \times 3}{13} = 2{,}307$ tons.

The stone should be sampled every few feet and taken from wall to wall in order to arrive at a fair estimate of its value.

In following up other minerals than gold, it must be borne in mind, that many of them have a tendency to decompose when exposed to the action of the weather, and, consequently, that the nature of the ore at the outcrop may be very different to what will be found in depth. Copper ores, for instance, are very liable to decompose and, forming sulphates which are soluble, to be carried away in solution by running water. As most copper ores are associated with a greater or less quantity of iron (see p. 165), the outcrops of copper lodes are very frequently represented by a porous ironstone, which is called

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"gossan," and no sign of copper is found until some depth has been sunk. Generally speaking, an outcrop of porous gossan may be looked upon as a very good indication for mineral in depth; whereas, a dense ironstone seldom leads to rich deposits of other mineral below.

There are certain points regarding the nature of the rocks which should be borne in mind; for instance, tinstone is never found at any great distance from the junction of granite with some other rock, generally slate (see p. 175); moreover, the class of granite in which tinstone occurs, is almost invariably one in which white mica forms an important constituent of the rock. Copper ores are in most cases associated with rocks of a dark green colour, such as diorite, &c., and some very large and important irregular deposits are associated with serpentine (see p. 169). Lead ores are largely associated with limestone formations, as also are ores of zinc; but, while all these points are worthy of attention, they must not be taken as forming any invariable rules.

Many of the irregular deposits to which attention has been drawn in the earlier pages of this book are of great value, and certain of the rarer minerals, such, for instance, as sulphide of bismuth and native bismuth are found in these deposits. A few remarks regarding the work of prospecting these will be of importance.

These irregular deposits are not only irregular in their mode of occurrence, but vary indefinitely both in size and shape; so that no one by surface indications is able to form any opinion regarding their extent. It is even more important in testing these deposits when an outcrop has been found, than it is in the case of a reef, to follow them carefully in the workings. Any drives or shafts which may be commenced should follow the direction of the ore, no matter how crooked this may be, as it will be quite time enough to sink vertical shafts to work the ore, after its extent has been proved as far as possible by these prospecting works. To sum up the question of development work which should be undertaken by prospectors, it may be said, "When the ore has been found, follow it!"

There are a number of minerals of value which hardly come under the heading of ores, such, for instance, as the non-metallic minerals which are used for industrial purposes. Amongst these may be mentioned witherite or carbonate of baryta, apatite or phosphate of lime, alunite or alumstone, fluor spar, and scheelite or tungstate of lime, all of which are valuable if found in considerable quantities and in easily accessible positions. Even

the better varieties of marble, gypsum, and lithographic stone, which occur as rocks; are worthy of some attention when well situated and of good quality; and deposits of ironstone, chromite, or manganese ores are all of value, if situated in positions which enable them to be shipped at low prices, and if they are sufficiently rich, say over 50 per cent. of the metal or chromic acid, to allow of their ready sale. The question of locality, however, is one which enters largely into the value of deposits such as these, and the best deposit of manganese with a long land carriage would be valueless and not worthy the attention of the prospector. In localities difficult of access, none but the most valuable ores are worthy of attention; and, generally speaking, it is only in the pursuit of gold or gems that such districts are likely to be prospected.

Nothing need be added to what has already been said regarding gems. They are nearly always found in alluvial drifts, indeed, the diamond has only been traced to its parent rock in the Transvaal. In prospecting any alluvial drifts it thus becomes a matter of importance to carefully examine any of the heavier stones found in panning, to see whether any of these valuable minerals exist.

Gold and silver frequently occur under conditions which render it impossible to recognise them, and estimate their value, except by assay. Gold, for instance, is very frequently associated with pyrites, and, where this is suspected, it is better to roast the finely crushed ore as long as any smell of burning sulphur can be detected, after which the gold can generally be seen in the pan; but it is necessary even then to assay the ore to determine what quantity of gold is present.

What has been said about gold is even more applicable to silver, for this metal seldom occurs in a native state, but is generally associated with galena or other lead ores, or with grey copper; although, of course, there are important deposits in which chlorides, sulphides, antimonides, &c., of silver occur. No estimate of the value of an argentiferous galena can be formed, except by assaying; consequently, all ores of this class should be so tested.

The practice of assaying gold-bearing quartz, as a general rule, is not to be advocated; as the returns are generally misleading, owing to the difficulty of taking average samples, and the fact that free gold is never equally disseminated through the stone, but occurs in grains, strings, &c., the rest of the stone being absolutely barren. In sampling pyritous ores or lodes carrying galena, for purposes of assay; indeed, in sampling any ore with

the object of making chemical tests regarding its contents, it is necessary to take as large samples as possible. These should be taken from all parts of the lode exposed, and, after having broken the large sample thus obtained to an uniform size, the material should be well mixed and quartered, that part selected being crushed finer again; and so on, until the last lot from which the sample for assay is taken should be reduced to powder. In sampling an ore in which the percentage of pyrites is comparatively small, it is frequently better to crush a fair quantity of it fine; and, having taken a weighed quantity, to concentrate by panning, and only to assay the concentrates. Of course, if this is done the weight of the concentrates obtained must be taken, and the assay results apportioned to the whole ore.

The methods of tracing coal have been so fully dealt with elsewhere (see p. 81), that it is hardly necessary to make any further remarks on the subject. It, therefore, only remains to recapitulate as briefly as possible a few hints for the guidance of prospectors.

It is obviously necessary that some attention should be devoted to mineralogy, not in the sense of distinguishing all the numerous varieties of minerals which exist, but the prospector should be able, by simple blowpipe tests, and some knowledge of their physical characters, to recognise with accuracy the more important and common minerals. Whenever he finds a mineral which he cannot recognise himself, it is always worth while keeping a specimen, and noting whence it came, for subsequent determination.

He should also make a study of the associations of minerals, noting the usual combinations which occur, and which have been alluded to through this book. The minerals which may be mistaken one for the other should also be carefully studied, and the tests which serve to distinguish them. The natures of the different classes of rock are also of importance, and every possible information should be stored in his mind regarding the minerals which occur associated with them in other localities; and, finally, so much stratigraphical geology should be known as to impress upon him the fact that the age of the rocks in a new locality has nothing whatever to do with their mineral contents.

Above all other things, however, the prospector must be practical, and must avoid forming theories until he has sufficient grounds from actual observation to support them. He must test his ground carefully, and examine all the details, which bear upon the question, dispassionately, with the object in view of

proving to himself whether, or no, any discovery he has made possesses the elements of a successful mine, if followed up. It is always an unpleasant thing to relinquish an undertaking which has been commenced; but it is much better to do this at once, when it is apparent that it will not pay, than to continue working an unprofitable affair.

The prospector has always to be careful not to deceive himself and not to be led to conclusions which he desires to form, if they are not supported by facts; and this is perhaps the most difficult lesson of all which he has to learn, and one which is sometimes never learnt satisfactorily. It should therefore be always remembered that, although every prospector must be sanguine of success, his hopes must be tempered by judgment.

GLOSSARY.

ABRADED,	Reduced to powder.
ACID,	A body containing hydrogen, which hydrogen may be replaced by a metal.
ACTINOLITE,	A variety of hornblende, see p. 60.
ADAMANTINE,	Diamond-like.
ADULARIA,	Silicate of alumina and potash; a variety of orthoclase.
AGATE,	Silica — mixtures of chalcedony in layers with jasper, amethyst, or quartz.
AGGREGATION,	A coherent group.
ALABANDINE,	Sulphide of manganese.
ALABASTER,	Hydrous sulphate of lime—a compact form of gypsum.
ALBITE,	Silicate of alumina and soda; a felspar.
ALKALIES,	Hydrates of potassium, sodium, lithium, and ammonium.
ALLOPHANE,	Hydrous silicate of alumina; a hardened clay.
ALLUVIAL,	Matter recently washed together by the action of water.
ALMANDINE,	Noble garnet.
ALUM,	A sulphate of alumina and either potash, soda. ammonia, magnesia, or iron; soluble in water.
ALUMINA,	Oxide of aluminium.
ALUMINIUM,	A metallic element.
ALUNITE,	Sulphate of alumina and potash; a source of alum.
AMALGAM,	A silver ore consisting of silver and mercury.
AMALGAMATION,	Intimate mixture; used to describe the absorption of gold by mercury and the methods of effecting this absorption.
AMBER,	A fossil gum.
AMETHYST,	Silica; a purple variety of quartz.
AMORPHOUS,	Having no definite crystalline form or structure.
AMPHIBOLITE,	Hornblende rock.
AMYGDALOIDS,	Small almond-shaped vesicular cavities in certain igneous rocks, partly or entirely filled with other minerals.
ANALCIME,	Hydrous silicate of alumina and soda; a zeolite.
ANAMESITE,	A variety of basalt of medium texture.
ANDALUSITE,	A silicate of alumina.

ANDESITE, .	An igneous rock composed of some glassy matter, plagioclase felspar and hornblende or augite, and sometimes quartz and magnetite.
ANGLESITE, .	Sulphate of lead.
ANHYDRITE, .	Sulphate of lime.
ANHYDROUS, .	Without water in its composition.
ANNABERGITE, .	Arseniate of nickel.
ANORTHITE, .	Silicate of alumina and lime ; a felspar.
ANTHRACITE, .	A non-bituminous coal.
ANTICLINE, .	A saddle back ; applied to strata when bent like the roof of a house.
ANTIMONIDES,	Combinations of antimony with metals.
ANTIMONY, .	A metallic element.
APATITE, .	A phosphate of lime.
APOPHYLLITE, .	A hydrous silicate of lime with potassium fluoride; a zeolite.
AQUAMARINE, .	A silicate of alumina and glucina ; a variety of beryl.
AQUEOUS ROCKS,	Rocks that have been deposited in water, whether as sediment or by chemical precipitation.
ARAGONITE, .	Rhombic carbonate of lime.
ARCHÆAN, .	Pre-Cambrian rocks—see *Geological Table.*
ARGENTIFEROUS,	Silver bearing.
ARGENTITE, .	Sulphide of silver.
ARKOSE, .	A rock formed by the disintegration of granite.
ARQUERITE, .	A silver ore consisting of silver and mercury.
ARSENIATES, .	Compounds of arsenic acid with bases.
ARSENIC, .	A metallic element.
ARSENIDES, .	Compound of arsenic with metals.
ASBESTOS,	A white variety of hornblende in long flexible filaments.
ASPHALTUM, .	A mineral resin.
AUGITE, .	A silicate of lime, magnesia, and iron.
AURIFEROUS, .	Gold bearing.
AZURITE, .	Blue carbonate of copper.
BACILLAR, .	Grouped in bundles like sticks.
BACKS, .	The ground between a level in a mine and the next workings above, or the surface.
BACK LEADS, .	A term applied to black sand "leads". on coast lines which are above high water mark.
BANDED VEINS, .	Veins made up of layers of different minerals parallel with the walls.
BANKET, .	Auriferous conglomerates cemented together with quartz.
BARREN, .	Not containing mineral of value.
BARYTES, .	Sulphate of baryta.
BARYTOCALCITE, .	Carbonate of baryta and lime.
BASALT, .	A volcanic rock ; see page 9.

Bases, . . .	Compounds which are converted into salts by the action of acids.
Battery, ...	A machine for crushing ores.
Bedded Veins, . . .	Veins running parallel with the strata in which they occur, both in strike and dip.
Bedding, . .	Stratification; the arrangement of strata in layers.
Bed Rock,	Compact rock underlying loose or incoherent strata, such as alluvial deposits.
Beds, . .	The thinner subdivisions of sedimentary rocks.
Beryl, ,	A silicate of alumina and glucina.
Biotite, .	Magnesian iron mica.
Bismuth, . .	A metallic element.
Bismuth Glance or Bismuthine,	Sulphide of bismuth.
Bismuth Ochre, .	Oxide of bismuth.
Bismuthite, . .	Hydrous carbonate of bismuth.
Bitumen, .	Pitch or tar.
Bituminous, . .	Containing pitch or tar.
Black Band Ironstone,	Argillaceous carbonate of iron with bituminous matter.
Black Jack, . .	Zinc blende.
Black Sand Beaches, .	Sands containing magnetite, specular iron or titanic iron.
Blende, .	Sulphide of zinc.
Bloodstone,	A dark green variety of quartz with specks or veins of jasper.
Blowpipe, .	An instrument to cast a current of air through a flame.
Boghead Mineral,	A shale containing a large percentage of hydrocarbons.
Boracite,	A borate and chloride of magnesia.
Borax, . . .	A borate of soda.
Boring, .	Sinking holes by means of rods or diamond drills.
Bornite, . .	Sulphide of copper and iron.
Botryoidal,	Like a bunch of grapes.
Bottom, .	See *False Bottom.*
Bournonite, .	Sulphide of lead, antimony, and copper.
Braunite, . . .	Anhydrous oxide of manganese.
Brazilian Emerald, .	A variety of tourmaline.
,, Sapphire, . .	,, ,,
Breccia, ...	A conglomerate of angular fragments.
Breithauptite, .	Antimonide of nickel.
Brine, ...	Water impregnated with salt.
Bromargyrite, .	Bromide of silver.
Bromide, . .	A compound of bromine with a metal.
Bromine, . . .	An element.
Bronzite,	A silicate of magnesia and iron.
Brookite, . . .	A form of oxide of titanium.

BROWN COAL,	Lignite; a hydrous coal.
BROWN IRON ORE,	Limonite; a hydrous oxide of iron.
BUNCHES,	Detached irregular masses of ore in a vein.
BUNTER SANDSTONE,	A sandstone at the base of the Triassic system.
BURIED RIVERS,	River beds which have been buried below streams of basalt or alluvial drifts.
CADMIUM,	A metallic element.
CAIRNGORM,	Smoky quartz.
CALAMINE,	Carbonate of zinc.
CALAVERITE,	Telluride of gold.
CALCAREOUS,	Containing carbonate of lime.
,, SINTER,	Calcareous deposit from water.
,, TUFA,	,, ,, ,,
CALCINATION,	Roasting at a gentle heat.
CALCITE,	Hexagonal carbonate of lime.
CALCIUM,	A metallic element.
CALOMEL,	Chloride of mercury.
CAMBRIAN,	See *Geological Table.*
CANNEL COAL,	A coal yielding a large quantity of illuminating gas.
CAPILLARY,	Hair-like.
CARAT,	$3\frac{1}{6}$ troy grains.
CARBONACEOUS,	Containing fossil carbon.
CARBONAS,	Irregular offshoots of mineral from lodes.
CARBONATES,	Compounds of carbonic acid with a base.
CARBONIC ACID,	Carbonic anhydride CO_2.
CARBONIFEROUS,	See *Geological Table.*
CARBONISATION,	Conversion to carbon.
CARNALLITE,	Chloride of magnesia and potash.
CARNELIAN,	A red variety of quartz.
CASING,	Clayey material found between a vein and its walls.
CASSITERITE,	Oxide of tin.
CAT'S EYE,	Oriental cat's eye is chrysoberyl and false cat's eye quartz enclosing fibres of asbestos.
CAUNTER LODE,	A diagonal lode.
CAVE DEPOSITS,	Irregular deposits of mineral in the caves generally found in limestone.
CELESTINE,	Sulphate of strontia.
CEMENT,	Auriferous conglomerate.
CERUSSITE,	Carbonate of lead.
CERVANTITE,	Oxide of antimony.
CHABAZITE,	Hydrous silicate of alumina, lime, potash, and soda; a zeolite.
CHALCANTHITE,	Sulphate of copper.
CHALCEDONY,	A variety of quartz.
CHALCOPYRITE,	Sulphide of copper and iron.

CHIASTOLITE, . .	Silicate of alumina.
CHLOANTHITE, . .	Arsenide of nickel.
CHLORIDES, .	Compounds of chlorine with metals.
CHLORINATION, .	Conversion of gold into chloride of gold by the action of chlorine.
CHLORINE,	An element.
CHLORITE, . .	A hydrous silicate of magnesia and alumina.
CHLOROBROMIDES,	Compounds of chlorine and bromine with metals.
CHROME IRON, .	A chromate of iron.
CHROMITE, . . .	,, ,,
CHROMIUM, . .	A metallic element.
CHRYSOBERYL, .	Aluminate of glucina ; a gem.
CHRYSOCOLLA, .	A hydrous silicate of copper.
CHRYSOLITE, . .	Silicate of magnesia and iron.
CHRYSOPRASE, .	An apple-green variety of quartz.
CHRYSOTILE, . . .	Hydrous silicate of magnesia ; a fibrous variety of serpentine.
CINNABAR, .	Sulphide of mercury.
CITRINE, . .	False topaz ; a yellow variety of quartz.
CLAY, . . .	A hydrated silicate of alumina in very finely divided particles.
CLAY SLATE, . . .	A slate formed by the induration of clay.
CLEAVAGE, . .	The property possessed by certain minerals and rocks of splitting more readily in certain directions than others.
CLEAVAGE PLANES,	The planes along which cleavage takes place.
CLINOMETER, . .	An instrument for measuring angles on a vertical wall face.
COAL, . . .	Fossilised carbon formed by the carbonisation of vegetable matter.
COBALT, . .	A metallic element.
COBALT BLOOM, . . .	Arseniate of cobalt.
COBALTIFEROUS WAD, . .	Impure oxide of manganese, containing cobalt.
COBALTIFEROUS MISPICKEL, .	Sulphide and arsenide of iron, containing cobalt.
COBALTINE, . . .	Sulphide and arsenide of cobalt.
COLUMNAR, ...	In the form of columns.
COLUMNS (OF ORE), . .	Deposits of ore in lodes having a small lateral, but considerable vertical, extent.
COMBED VEINS, . .	See *Banded Veins*.
COMBUSTIBLE, . . .	Capable of being burned.
CONCHOIDAL, . .	Shell-like.
CONCRETION, . . .	A nodule formed by the aggregation of mineral matter from without round some centre.
CONGENIAL, ...	A term applied to rocks in which lodes become ore-bearing.
CONGLOMERATE, . . .	Consolidated gravel.
CONTACT DEPOSITS, . .	Mineral deposits occurring at the line of junction of two dissimilar rocks.

CONTORTION, . . .	Crumpling and twisting.
COPPER, . .	A metallic element.
COPPERAS, . . .	Sulphate of iron.
COPPER GLANCE, . .	Sulphide of copper.
COPPER NICKEL, . .	Arsenide of nickel.
COPPER PYRITES, . . .	Sulphide of copper and iron.
COPPER SLATE, . . .	Slate impregnated with copper minerals.
COPROLITES, . .	Phosphate of lime; petrified excrements of animals.
CORDIERITE, ...	Silicate of alumina, iron, and magnesia; a gem.
CORUNDUM, ...	Alumina; a gem.
COTERMINOUS, . . .	Finishing at the same point.
COURSES (OF ORE), . .	Deposits of ore in lodes having a small vertical, but considerable lateral, extent.
COVELLINE, ...	Sulphide of copper.
CRADLE, . . .	An apparatus for washing alluvial gold, mounted on rockers.
CRATE DAM,. . . .	A dam built of crates filled with stones.
CRATERIFORM, . . .	In the form of a crater.
CRETACEOUS, . . .	See *Geological Table.*
CREVICING, ...	Searching the crevices in rocks forming the beds of streams in search for gold.
CROCIDOLITE,	A fibrous silicate of iron, soda, and magnesia.
CROCOISITE, ...	Chromate of lead.
CROSS COURSE, . .	A vein intersecting another of greater geological age, which it frequently displaces from its original course.
CRYOLITE, ...	Fluoride of alumina and soda.
CRYSTALLISATION, . .	The assumption by matter of a definite geometrical form.
CUBE, ...	A solid six-sided figure, of which each of the sides is a square and all the angles right angles.
CUPRITE, ...	Red oxide of copper.
CYANIDATION, . . .	Conversion of gold into a double cyanide of potassium and gold by the action of cyanide of potassium.
CYANITE, . . .	A silicate of alumina.
DEAD WORK, . . .	Work in unproductive ground.
DECREPITATE, . . .	Explosive breaking up into fragments when heated before the blow-pipe.
DEEP LEADS, . . .	Alluvial deposits of gold or tinstone buried below a considerable thickness of soil or rock.
DEGRADATION, . . .	Wearing away.
DEHYDRATED, . . .	Deprived of water.
DENDRITIC, ...	Like branches of trees.
DENUDATION, . . .	Stripping by water and other agents.

DETRITUS, . .	Accumulations from the disintegration of exposed rock surfaces.
DEVONIAN. .	See *Geological Table.*
DIABASE, . . .	An igneous rock, see p. 9.
DIALLAGE, .	A silicate of lime and magnesia.
DIALLOGITE,	Carbonate of manganese.
DIAMOND, . .	Crystallised carbon; a gem.
DIATOMS, . .	Minute plants which are provided with siliceous envelopes.
DICHROIC, . .	Exhibiting two different colours when light is transmitted in two different directions.
DICHROITE, . .	Cordierite; a silicate of alumina, iron, and magnesia.
DIOPSIDE, . . .	A silicate of lime and magnesia.
DIOPTASE, ...	A silicate of copper.
DIORITE, . . .	An igneous rock, see p. 9.
DIP, ...	The angle of inclination of beds or strata measured in relation to a horizontal line.
DISINTEGRATION, .	The breaking asunder of solid matter due to chemical or physical forces.
DISLOCATION, .	The displacement of rocks on either side of a crack.
DISTHENE, . .	Cyanite; a silicate of alumina.
DOLERITE, .	An igneous rock; see p. 9.
DOLOMITE, . . .	Carbonate of lime and magnesia.
DOMES, ...	Strata which are dipping away in every direction.
DOMEYKITE, .	Arsenide of copper.
DREDGING, . . .	Raising material from below water by means of a dredge.
DRIFT, ...	Loose crumbly alluvial deposits.
DRUSY, . .	Cavities in rocks lined with crystals.
DRY ORES, . .	Silver ores which do not contain lead.
DUCTILE, . .	Capable of being drawn into wire.
DUMP, ...	A space below place of delivery where tailings can be deposited.
DUNITE, ...	A massive olivine rock in which small grains of chromite are interspersed.
DYKE, ...	A vertical or highly dipping injected sheet of eruptive origin.
EFFLORESCENCE, . .	Crystals or powder formed on the surface of minerals, due to their decomposition.
ELASTIC, ...	Substances capable of being stretched and then resuming their original form.
ELATERITE, . . .	Elastic bitumen; a hydrocarbon.
ELECTRUM, . . .	An alloy of silver and gold.
ELEMENTS, ...	Substances which have never been decomposed.
ELEVATION, . .	A front or side view of anything.
ELVAN, ...	An igneous rock, see p. 9.

EMBOLITE,	Chlorobromide of silver.
EMERALD,	A silicate of alumina and glucina; a gem.
EMERY,	An impure variety of corundum.
ENARGITE,	Sulphide, arsenide, and antimonide of copper.
ENSTATITE,	A silicate of magnesia and iron.
EOCENE,	See *Geological Table.*
EPIDOTE,	A hydrous silicate of alumina, iron, and lime.
EPSOM SALT,	Hydrous sulphate of magnesia.
ERODING,	Gradually wearing away.
ERUBESCITE,	Bornite; sulphide of copper and iron.
ERUPTIVE,	Formed by a violent breaking out of enclosed matter.
ERYTHRINE,	Arseniate of cobalt.
EXCRESCENCE,	Grown out of.
EXFOLIATE,	To peel off in leaves from the outside.
FAHLBANDS,	Zones of crystalline schists impregnated with metallic sulphides which influence the richness of lodes passing through them.
FALSE BOTTOM,	In alluvial mining a stratum on which auriferous beds lie, but which has other bottoms below it.
FAULT,	A displacement of the strata accompanied by a fracture of the rock.
FELSPARS,	Anhydrous silicates of alumina and of an alkali or lime.
FERRUGINOUS,	Containing iron.
FIBROUS,	Consisting of fibres which cannot be easily separated.
FIRECLAY,	A silicate of alumina that will stand intense heat; it is almost entirely free from alkalies or lime.
FISSURES,	Open cracks.
FISSURE LODES,	A lode occupying what was once a fissure opened by a movement of the rocks.
FLATS (OF ORE),	A horizontal ore deposit occupying a bedding plane in the rock.
FLOCCULENT,	Cloudy, resembling lumps of wool.
FLOOR,	The bottom of a coal seam.
FLUCAN,	A soft clayey substance, casing.
FLUOR SPAR,	Fluoride of lime.
FOOTWALL,	The lower side or boundary of a lode.
FOSSILIFEROUS,	Rocks containing fossils.
FOSSILS,	The remains of plants or animals accidentally buried in the earth.
FRANKLINITE,	Oxide of iron, zinc and manganese.
FREE MILLING,	Ores which yield their gold or silver to amalgamation.
FREISLEBENITE,	A sulphide of silver, lead, and antimony.
FULLERS EARTH,	Soft unctuous clays employed in the treatment of woollen goods.

GABBRO,	An igneous rock, see p. 9.
GALENA,	Sulphide of lead.
GALMEI,	A silicate of zinc.
GANGUE,	The matrix in a lode in which ore occurs.
GARNETS,	Anhydrous silicates of alumina and the earths coloured by oxides of iron, manganese and chromium.
GARNIERITE,	A silicate of nickel.
GASH VEINS,	Fissures which are confined to particular rocks or beds and which do not extend into adjoining rocks.
GE-ANTICLINAL,	Dome-shaped bendings, not only of the strata or formation, but of the earth's crust covered with its strata which may or may not be contorted.
GELATINISE,	Become like jelly.
GEOLOGICAL TABLE,	The rocks which constitute the earth's crust are divided according to their relative position and fossil contents as in the following table ; those at the top of the table being the youngest.

Post Tertiary—Recent and Pleistocene.

Tertiary (Cainozoic),	Pliocene. Miocene. Oligocene. Eocene.
Secondary (Mesozoic),	Cretaceous. Jurassic. Triassic.
Primary (pt.) (Palæozoic),	Permian. Carboniferous. Devonian. Silurian. Cambrian.
Primary (pt.) (Azoic),	Archæan.

GEO-SYNCLINAL,	Basin-shaped bendings of the earth's crust, the reverse of ge-anticlinals.
GERSDORFFITE,	An arsenide of nickel.
GEYSERS,	Intermittent boiling springs.
GLACIAL DEPOSITS,	Deposits formed by the ice sheets of the glacial period.
GLACIER DEPOSITS,	Deposits formed by existing glaciers or their former extensions.
GLAUBER SALT,	Sulphate of soda.
GLAUCODOTE,	A variety of cobaltine.
GNEISS,	A stratified granitoid rock in which the minerals are arranged in layers.
GOETHITE,	A hydrous oxide of iron.
GOLD,	A metallic element.
GOSLARITE,	Sulphate of zinc.

GOSSAN,	Hydrated peroxide of iron often quartzose, found capping lodes that contain ferruginous minerals.
GRANITE,	An igneous rock, see p. 9.
GRANULAR,	In the form of grains.
GRAPHITE,	A form of carbon.
GREISEN,	A granitic rock consisting of mica and quartz.
GREY COPPER,	Tetrahedrite; a complex copper ore; see p. 163.
GROSSULARIA,	A green variety of garnet.
GYPSUM,	Hydrous sulphate of lime.
HÆMATITE,	Anhydrous oxide of iron.
HALLOYSITE,	A hard clay.
HANGING WALL,	The upper side or boundary of a lode opposite the foot wall.
HARMOTOME,	Hydrous silicate of alumina and baryta.
HAUERITE,	Sulphide of manganese.
HAUSMANNITE,	Anhydrous oxide of manganese.
HAUYNE,	Silicate of alumina, soda, and lime, and sulphate of lime.
HEAVE,	An apparent lateral displacement of a lode produced by a fault.
HEDENBERGITE,	Black variety of augite.
HELIOTROPE,	Bloodstone; a dark green variety of quartz with specks or veins of jasper.
HESSITE,	Telluride of gold.
HEULANDITE,	Hydrous silicate of alumina and lime; a zeolite.
HOMOGENEOUS,	Of the same structure throughout.
HORNBLENDE,	A silicate of lime, magnesia, and iron.
,, ANDESITE,	An igneous rock; see p. 9.
HORN SILVER,	Chloride of silver.
HUMID,	Warm and moist.
HYACINTH,	A variety of zircon.
HYDRAULIC ELEVATOR,	A machine for raising gravel by means of hydraulic pressure.
HYDRAULIC LIME,	Lime which has the property of setting under water.
HYDROCARBONS,	Compounds of carbon and hydrogen.
HYDROMAGNESITE,	Hydrous carbonate of magnesia.
HYDROTHERMAL,	Pertaining to hot water, especially with respect to its action in dissolving, re-depositing and otherwise producing mineral changes within the crust of the globe.
HYDROUS,	Containing water regarded as water of crystallisation.
HYPERSTHENE,	A silicate of magnesia and iron.
HYPERSTHENITE,	A rock formed of labradorite and hypersthene.
ICELAND SPAR,	Crystallised transparent carbonate of lime.
IDOCRASE,	A silicate of alumina, lime, and magnesia.
IGNEOUS,	Applied to all agencies, operations, and results which appear to be connected with subterranean heat.

IMPOUNDING TAILINGS, . .	Enclosing them so that they cannot flow where they are not wanted.
IMPREGNATION, . . .	Ore disseminated through rock and having no sharply-defined limits.
INDICATOR VEIN, . . .	A vein which is not metalliferous itself, but, if followed, leads to ore deposits.
INDURATED, . . .	Hardened.
INFUSORIAL EARTH,	A siliceous deposit formed chiefly of fragments of diatoms.
IN SITU, ...	In the place where formed.
INTERSTRATIFIED, . .	Interbedded with.
INTRUSION, ...	Forcing through.
INTUMESCENCE, . . .	Swelling when heated.
IODARGYRITE, . .	Iodide of silver.
IODINE, ...	A metallic element.
IRIDESCENT, ...	Exhibiting a play of different colours like a rainbow.
IRIDIUM, . .	A metallic element.
IRIDOSMINE, . . .	An alloy of iridium and osmium.
IRON, ...	A metallic element.
IRON PYRITES, . . .	Sulphide of iron.
ISOMORPHISM, . . .	The property of certain chemical compounds of different composition, but crystallising in the same forms, of replacing one another in minerals.
ITACOLUMITE, . . .	A flexible sandstone.
JADE, ...	Nephrite; a silicate of lime, magnesia, and iron.
JAMESONITE, ...	A sulphide of lead and antimony.
JARGON, ...	A variety of zircon.
JET, ...	A hard variety of coal, which is cut and polished for ornaments.
JIGGER, ...	A machine for the concentration of ores.
JURASSIC, . . .	See *Geological Table*.
KAOLIN, ...	A very pure clay.
KAURI GUM, . . .	A gum which exudes from the kauri pine in New Zealand, and is frequently found fossilised.
KERARGYRITE, . . .	Chloride of silver.
KEROSENE SHALE, . .	A shale containing a large proportion of hydrocarbons of high illuminating power.
KILLAS, ...	Clay slate.
KINDLY GROUND, . .	Those rocks in which lodes become productive of mineral of value.
KYANITE, . . .	See *Cyanite*.
LABRADORITE, ...	A silicate of lime, alumina, and soda.
LACCOLITES, ...	Lenticular sheets of eruptive rock spread between beds, having an intrusive origin and not occurring as an overflow.

LAMELLAR,	In thin sheets.
LAMINÆ,	Thin plates or scales.
LAPIS LAZULI,	Ultramarine, see p. 77.
LAUMONTITE,	A silicate of lime and alumina.
LAVAS,	Rocks which have flowed in a molten state from volcanoes.
LEADERS,	Small veins carrying mineral which are offshoots from lodes.
LEADS,	The auriferous portions of alluvial deposits marking the former course of the stream.
LENTICULAR,	Lens-like.
LEPIDOLITE,	A lithia mica.
LHERZOLITE,	A variety of pyroxene-olivine-rock.
LIBETHENITE,	Phosphate of copper.
LIGNITE,	A hydrous variety of coal retaining its woody structure.
LIME,	Oxide of calcium, produced by calcining carbonate of lime.
LIMESTONE,	Rock formed of carbonate of lime.
LIMONITE,	Hydrous oxide of iron.
LINNÆITE,	A sulphide of nickel and cobalt.
LITHOGRAPHIC STONE,	A very fine grained limestone.
LIVE RIVERS,	Rivers which are now running.
LODE,	Any vein that appears likely to produce metallic ore.
LODE FORMATION,	A term applied in many cases to decomposed rocks with small leaders traversing them.
MAGMA,	Paste or groundwork of igneous rocks.
MAGNESIA,	Oxide of magnesium.
MAGNESITE,	Carbonate of magnesia.
MAGNETIC PYRITES,	Pyrrhotine; a sulphide of iron.
MAGNETITE,	Magnetic oxide of iron.
MAIN BOTTOM,	Hard rock below alluvial deposits.
MALACHITE,	Green carbonate of copper.
MALLEABLE,	Capable of being moulded.
MAMMILLARY,	In smooth, rounded prominences.
MANGANESE,	A metallic element.
MANGANITE,	Hydrous oxide of manganese.
MARBLE,	Metamorphic limestone.
MARCASITE,	Radiated pyrites; rhombic sulphide of iron.
MARTITE,	A variety of hæmatite.
MATRIX,	The rock or mineral containing metallic ores or precious stones.
MEERSCHAUM,	A hydrous silicate of magnesia.
MELACONITE,	Black oxide of copper.
MELANITE,	A black variety of garnet.
MELAPHYRE,	An igneous rock.
MERCURY,	A metallic element.

METALLIFEROUS, . . .	Metal bearing.
METAMORPHISM, . . .	A term used to express a change in the mineralogical or chemical composition and internal structure of rocks produced by the operation of heat, heated water or vapour, pressure, &c.
METEORIC IRON, . . .	Iron which has fallen on the earth from interplanetary space.
MICAS, ...	Flexible and elastic minerals occurring in thin plates; silicates of alumina and potash, magnesia, lithia, or iron.
MICA SCHIST, . . .	A metamorphic rock consisting of a laminated aggregate of quartz and mica.
MILLERITE, ...	Sulphide of nickel.
MIMETITE, . . .	Arseniate of lead.
MINIUM, ...	Red lead; oxide of lead.
MIOCENE, ...	See *Geological Table.*
MISPICKEL, . . .	Sulphide and arsenide of iron.
MOLYBDENITE, . . .	Sulphide of molybdenum.
MOLYBDENUM, . .	A metallic element.
MOLYBDITE, ...	Molybden-ochre; oxide of molybdenum.
MOONSTONE, . .	A variety of adularia felspar.
MORAINES, ...	Deposits formed by glaciers.
MOUNTAIN LEATHER, . .	Impure asbestos.
MUNDIC, . . .	Pyrites; sulphide of iron.
MUSCOVITE, ...	Potash mica.
NACREOUS, ...	Resembling mother of pearl.
NAGYAGITE, ...	Telluride of gold and lead.
NATROLITE, ...	Hydrous silicate of alumina and soda; a zeolite.
NATRON, ...	Carbonate of soda.
NEPHRITE, ...	Jade; a silicate of lime, magnesia, and iron.
NEPTUNISTS, . . .	Those who ascribe all geological phenomena to the action of water.
NICKEL, . . .	A metallic element.
NICKELINE, ...	Arsenide of nickel.
NICKEL OCHRE, . . .	An arseniate of nickel.
NICOPYRITE, . . .	Sulphide of nickel and iron.
NITRATES, . .	Compounds of nitric acid with bases.
NITRATINE, ...	Nitrate of soda.
NODULAR, ...	Concretions of rock matter aggregated round a central nucleus.
NOUMEITE, ...	Silicate of nickel.
NUCLEUS, ...	A body about which anything is collected.
OBSIDIAN, . . .	A volcanic glass.
OCTAHEDRITE, . .	Titanic oxide.
OCTAHEDRON, . . .	An eight-sided figure, each of the sides being an equilateral triangle.
ODONTOLITE, ...	False turquoise; fossil bone coloured by copper.

Oligiste,	An oxide of iron (hæmatite).
Oligoclase,	Silicate of alumina, soda and lime; a soda-lime felspar.
Olivine,	Silicate of magnesia and iron.
Onyx,	A variety of quartz in alternate layers of white and brown or white and black.
Opal,	Hydrous silica.
Opalescence,	Exhibiting a play of colours like the precious opal.
Organic Compounds,	Compounds containing carbon, generally derived from animals or plants.
Oriental Amethyst,	A variety of corundum.
,, Emerald,	,, ,
,, Topaz,	,, ,,
Orpiment,	A sulphide of arsenic.
Orthoclase,	A silicate of alumina and potash; potash felspar.
Outcrop,	The appearance on the surface of the ground of a rock, lode, or coal seam.
Oxides,	Compounds of oxygen with any element.
Ozokerite,	Mineral wax; a solid petroleum.
Pack Walls,	Walls built of loose material in mines to support the roof.
Palladium,	A metallic element.
Pan Amalgamation,	Amalgamation of silver or gold with mercury by grinding in a pan.
Partings,	Small bands of shale or stone occurring in a coal seam.
Peacock Ore,	Copper pyrites which has become tarnished.
Pearly,	Resembling mother of pearl.
Pegmatite,	Veins of coarsely crystallised granite in granite.
Pennine,	A variety of chlorite.
Perlite,	A volcanic glass.
Permian,	See *Geological Table.*
Petrified,	Changed to stone.
Petroleum,	A natural mineral oil.
Petrology,	The study of rocks.
Petzite,	Telluride of silver and gold.
Phenakite,	A silicate of glucina; a gem.
Phosphates,	Compounds of phosphoric acid with a base.
Pipes (of Ore),	An elongated body of ore in limestone, generally standing nearly vertical.
Pisolitic Ores,	In concretions about the size of a pea.
Pitchblende,	Oxide of uranium.
Pitchstone,	A volcanic glass, see p. 9.
Plagioclase,	Felspars in which the two principal cleavage planes are not at right angles to one another.
Plasma,	A green variety of quartz.
Plastic,	Easily moulded.

PLATINIRIDIUM, . . .	An alloy of platinum and iridium.
PLATINUM, ...	A metallic element.
PLEONASTE, . . .	A variety of spinel.
PLICATIONS, . .	The smaller foldings of a rock.
PLIOCENE, . .	See *Geological Table.*
PLUMBAGO, ...	Graphite ; carbon.
PLUMB BOB, ...	A weight suspended by a string used to determine vertical lines.
PLUTONISTS, . . .	Those who attempt to explain all geological phenomena by the action of heat.
POLYBASITE, ...	A sulphide of silver, copper, antimony, and arsenic.
PORCELAIN CLAY, . . .	Kaolin, the purest form of clay.
PORPHYRITE, ...	An igneous rock consisting essentially of a true porphyry ground mass containing crystals of plagioclase.
PORPHYRY, ...	Any igneous rock consisting of a ground mass in which conspicuous crystals are embedded.
POSITION BLOCKS, .	Mining claims which are in a position which will contain a lode if it continues in the direction in which it has been proved in other claims, but which themselves have not yet been proved.
POTASH, ...	Oxide of potassium.
PRECIPITATE, . .	A solid substance thrown down in one solution by the addition of another solution.
PREHNITE, . . .	A silicate of alumina and lime.
PRISMATIC, .	In prisms.
PRISMS, . . .	Solids whose bases are plane figures, and whose sides are parallelograms.
PRODUCTIVE, . . .	Yielding payable ore.
PROPYLITE, .	Originally defined as tertiary volcanic rocks consisting of triclinic felspar and hornblende in a fine-grained non-vitreous ground mass.
PROSPECTING, . .	Searching for minerals.
PROUSTITE, . . .	A sulphide and arsenide of silver.
PSILOMELANE, . .	Manganate of baryta.
PUMICE, ...	A vesicular volcanic glass.
PURPLE OF CASSIUS, .	A purple precipitate formed by adding stannous chloride to chloride of gold.
PYRARGYRITE, . . .	A sulphide and antimonide of silver.
PYRITES, . .	Cubic sulphide of iron.
PYROLUSITE, ...	Black oxide of manganese.
PYROMORPHITE, . .	Phosphate of lead.
PYROPE, ...	A variety of garnet.
PYROSMALITE, . . .	A silicate of iron and magnesia.
PYRRHOTINE, . .	Magnetic pyrites ; sulphide of iron.
QUARRIED, . . .	Worked in the open.
QUARTZ, . . .	Crystallised silica.

QUARTZ DIORITE, .	An igneous rock, see p. 9.
QUARTZITE, . .	A metamorphic sandstone.
QUARTZ PORPHYRY,	An igneous rock, see p. 9.
QUICKLIME, . . .	Oxide of calcium produced by roasting limestone.
QUICKSILVER, . .	Mercury; a metallic element.
RADIATING, . . .	Diverging from a centre.
RAMIFIED,	Branched in many directions.
REALGAR,	Sulphide of arsenic.
RED LEAD, . .	Minium; oxide of lead.
REDRUTHITE, . . .	Copper glance; sulphide of copper.
REDUCTION, . .	Reducing compounds to a metallic state.
REEFS, .	Lodes, ledges, or veins.
REFRACTION, . .	Deviation from a direct course; the property possessed by some minerals of deflecting rays of light.
REFRACTORY,	Difficult to treat for the recovery of metals.
RENIFORM, .	Kidney-like.
RESINOUS, . . .	Resembling resin.
RETICULATED VEINS, .	Veins traversing rocks in all directions.
REVERSE FAULTS, .	Faults due to thrust, the hanging wall side of the fault being forced upwards on the footwall.
RHODONITE, . . .	Silicate of manganese.
RHOMBIC DODECAHEDRON, .	A twelve-sided figure, each side of which is a rhomb.
RHOMBOHEDRON, .	A six-sided figure, each side of which is a rhomb.
RHYOLITE, .	An igneous rock, see p. 9.
RIBBON VEINS, . .	See *Banded Veins*.
RIM ROCK,	Bed rock in alluvial mining which outcrops above the level at which the auriferous lead occurs.
RIPIDOLITE, . .	A variety of chlorite.
RISE, . .	That portion of a bed or coal seam which lies above a level is said to be "to the rise."
ROCK CRYSTAL, .	A clear colourless variety of quartz.
ROCK SALT, . .	Chloride of sodium.
ROOF, ...	The strata immediately above a coal seam.
RUBELLITE, ...	A red variety of tourmaline.
RUBY, ...	" " corundum.
RUTILE, . . .	A form of oxide of titanium.
SACCHAROID, . . .	Like lump sugar.
SADDLE REEFS, . .	Quartz reefs occurring in the form of saddles; see p. 141.
SAL-AMMONIAC, . . .	Chloride of ammonium.
SALTPETRE, . .	Nitrate of potash.
SAMPLING, . .	Mixing ores so that a portion taken may fairly represent the whole body.
SANDSTONE, . . .	Consolidated sand.

SANIDINE,	Silicate of alumina and potash ; a glassy variety of orthoclase.
SAPPHIRE,	A blue variety of corundum.
SARDONYX,	A variety of quartz.
SAURIANS,	A group of reptiles now extinct.
SCARP,	A steep face.
SCHEELITE,	Tungstate of lime.
SCHIST,	A laminated metamorphic rock.
SCHORL,	A black variety of tourmaline.
SECTILE,	Can be cut with a knife.
SECTION,	A cut through.
SEDIMENT,	A deposit formed by water.
SEDIMENTARY,	Rocks composed of sediment.
SEGREGATIONS,	Aggregations of ores in a cavity having an irregular form but defined limits.
SELENIUM,	An element.
SERPENTINE,	Hydrous silicate of magnesia.
SHALE,	Consolidated clay.
SHINGLE,	Clean gravel.
SHOOTS,	Deposits of ore in lodes, which have a limited lateral extent but considerable extent in depth ; they generally dip at varying angles between horizontal and vertical.
SIDERITE,	Carbonate of iron.
SILICA,	An oxide of silicon.
SILICATES,	Compounds of silica or silicic acid with a base.
SILURIAN,	See *Geological Table.*
SILVER,	A metallic element.
SILVER GLANCE,	Sulphide of silver.
SINTER,	A deposit from hot springs.
SLAGS,	Fusible silicates formed when ores are smelted and the metals extracted.
SLATE,	Indurated clays, sometimes metamorphosed.
SLICKENSIDES,	Smooth, polished, and sometimes striated surfaces on the walls of lodes produced by friction.
SLIDE,	A fault or cross course.
SLIMES,	The very fine grained particles produced by crushing ores, which do not readily sink in water.
SLUDGE CHANNEL,	Tail race for conveying the tailings away after the gold has been extracted from alluvial beds.
SLUICE BOX,	A wooden trough in which alluvial beds are washed for the recovery of gold or tinstone.
SLUICING TABLE,	A table on wheels used for washing black sand for gold on the coast of New Zealand.
SMALTINE,	Arsenide of cobalt.
SMITHSONITE,	Carbonate of zinc (Dana).
SOAPSTONE,	A compact variety of talc.

SODA, ...	Oxide of sodium.
SOLFATARIC ACTION,	The final stage of volcanic eruption when steam and gases only are emitted from the craters.
SPATHIC IRON, .	Carbonate of iron.
SPHEROSIDERITE,	do. do.
SPINEL, . . .	Aluminate of magnesia.
STALACTITES, . .	Icicle-like incrustations hanging down from the roof of caves.
STALAGMITES, . .	Similar to stalactites, but formed on the floor of the caves by the deposition of solid matter held in solution by dropping water.
STANNINE, . .	Sulphide of tin and copper.
STEATITE, .	Hydrous silicate of magnesia.
STEPHANITE, .	Sulphide and antimonide of silver.
STERNBERGITE,	Sulphide of silver and iron.
STIBNITE, . .	Sulphide of antimony.
STILBITE, .	Hydrous silicate of alumina and lime.
STOCKWORKS, .	Rock which is traversed by so many metalliferous veins as to render the whole deposit of sufficient value for treatment.
STRATIFICATION, .	The arrangement of sedimentary rocks in beds or strata.
STREAK, ...	The powder of a mineral or the colour-effect produced by scratching it with a knife.
STRIATED,	Marked with furrows.
STRIKE, . . .	A horizontal line upon the floor of a bed or footwall of a lode.
STROMEYERINE, .	Sulphide of silver and copper.
STRONTIA, . .	Oxide of strontium.
STRONTIANITE,	Carbonate of strontia.
STRONTIUM, . .	An element.
SULPHATES, .	Compounds of sulphuric acid with a base.
SULPHIDES,	Compounds of sulphur with metals.
SULPHUR, . .	An element.
SULPHURETTED HYDROGEN, .	A sulphide of hydrogen.
SUNSTONE, . .	A variety of oligoclase.
SURFACE CHARGES,	All expenses incurred on the surface of a mine which have to be charged against the mineral.
SYENITE, .	An igneous rock, see p. 9.
SYLVANITE, .	Telluride of gold and silver.
SYNCLINE, . .	Strata bent in the form of a trough.
TACHYLYTE, .	A volcanic glass.
TAILINGS, .	The refuse from a mine after the valuable ore have been extracted.
TAIL RACE, .	A channel for removing tailings
TALC, . .	A hydrous silicate of magnesia.
TELLURIUM, . . .	A metallic element.

TENNANTITE,	A sulphide and arsenide of copper and iron.
TETRAHEDRITE,	A complex copper ore, see p. 163.
THOMSONITE,	Hydrous silicate of alumina, lime, and soda; a zeolite.
TILL,	A glacial deposit.
TIMAZITE,	Hornblende andesite.
TIN DISH,	A dish used by prospectors for washing gold-bearing materials and extracting the gold.
TIN PYRITES,	Sulphide of copper and tin.
TINSTONE,	Cassiterite; oxide of tin.
TITANATES,	Compounds of titanic acid with a base.
TITANIC IRON,	Specular iron containing oxide of titanium.
TITANIUM,	A metallic element.
TOAD'S EYE TIN,	A variety of wood tin occurring in small spherical particles embedded in a mass of darker or lighter colour.
TOPAZ,	A silicate of alumina with fluorine; a gem.
TORBANITE,	A dark brown variety of cannel coal.
TOURMALINE,	A silicate of alumina and other oxides, see p. 74.
TRACHYTE,	An igneous rock, see p. 9.
TRANSLUCENT,	Transmitting light, but not transparent.
TRANSPARENT,	Transmitting light perfectly; objects can be seen through a transparent medium.
TRAPPEAN,	Rocks occurring in dykes and sheets.
TRAVERTINE,	Material deposited by calcareous springs.
TREMOLITE,	A white variety of hornblende.
TRIASSIC,	See *Geological Table*.
TRICLINIC,	Crystals having three axes which are not at right angles.
TRIDYMITE,	Silica—resembling quartz, but occurring in small flat hexagonal tables.
TRIPOLI,	A hydrous silica powder composed chiefly of diatoms.
TROUBLES,	Disturbances in a coal seam.
TUNGSTATES,	Compounds of tungstic acid with a base.
TUNGSTEN,	A metallic element.
ULTRAMARINE,	Lapis lazuli, see p. 77.
UNDERCLAY,	The clay forming the floor of many coal seams.
UNDERLAY,	The inclination of lodes to the vertical.
URANIUM,	A metallic element.
UWAROWITE,	A chrome garnet.
VALENTINITE,	Oxide of antimony.
VESUVIANITE,	A silicate of alumina, lime, and magnesia.
VITREOUS,	Glassy.
VIVIANITE,	Hydrous phosphate of iron.
VOLCANIC,	Ejected from a volcano.

WAD,	An impure earthy ore of manganese.
WASH OUTS,	Parts of coal seams which have been removed by streams flowing at the time of their formation.
WATER POWER,	The power which is developed by the pressure of water when applied to water wheels, turbines, &c.
WILLEMITE,	Anhydrous silicate of zinc.
WING DAMS,	Dams built from the side of a river with the object of deflecting it from its course.
WITHERITE,	Carbonate of baryta.
WOLFRAM,	Tungstate of iron and manganese.
WOLLASTONITE,	A silicate of lime.
WOOD TIN,	Tinstone of a brown colour of various shades; botryoidal and reniform in shape and fibrous in structure.
WULFENITE,	Molybdate of lead.
ZEOLITES,	Hydrous silicates of alkalies or alkaline earths with silicates of alumina.
ZINC,	A metallic element.
ZINC BLENDE,	Sulphide of zinc.
ZINC BLOOM,	Hydrous carbonate of zinc.
ZINCITE,	Red oxide of zinc.
ZINCKENITE,	Sulphide of lead and antimony.
ZIRCON,	A silicate of zirconia; a gem.
ZOISITE,	A non-ferriferous rhombic ally of epidote.
ZWITTER ROCK,	A stockwork porphyry at Altenberg.

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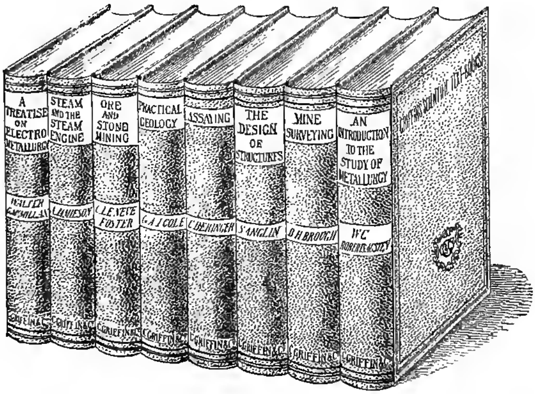

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